628.1686
STUDY
v. VII

A Study of Toxicity and Biostimulation in San Francisco Bay–Delta Waters

VOLUME VII

EFFECTS OF WASTES ON BENTHIC BIOTA

PUBLICATION 44

1972

CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

CALIFORNIA

Ronald Reagan, Governor

The Resources Agency
STATE WATER RESOURCES CONTROL BOARD

W. W. Adams, Chairman
Ronald B. Robie, Vice Chairman
Roy E. Dodson
Mrs. Carl H. (Jean) Auer
W. Don Maughan

Bill B. Dendy, Executive Officer

ILLINOIS STATE LIBRARY
SPRINGFIELD
628.1686 STUD v.VII
A study of toxicity and biostimulation in San Francisco Bay-Delta waters

7406564

ILLINOIS STATE LIBRARY

A STUDY OF TOXICITY AND BIOSTIMULATION IN SAN FRANCISCO BAY–DELTA WATERS

VOLUME VII

EFFECTS OF WASTES ON BENTHIC BIOTA

STATE WATER RESOURCES CONTROL BOARD
Standard Agreement No. 260809

By
Dick A. Daniel
Harold K. Chadwick
California Department of Fish and Game

WITHDRAWN

7406564

ILLINOIS STATE LIBRARY
3 1129 00589 6030

October 1971

ILLINOIS STATE LIBRARY

Digitized by the Internet Archive
in 2022 with funding from
University of Illinois Urbana-Champaign Alternates

https://archive.org/details/studyoftoxicityb07unse

FOREWORD

The San Francisco Bay and contiguous Sacramento-San Joaquin Delta currently receive wastewaters from nearly five million people situated in the nine surrounding counties. This is one of the most rapidly expanding metropolitan and industrial areas in the nation. Its water resource provides extensive recreational, commercial and industrial benefits, in addition to use for wastewater disposal.

In October 1966, the State Water Resources Control Board was directed by the Legislature to conduct a comprehensive study of the effects of wastewater and drainage discharges into the Bay and Delta and to develop the basic features of a comprehensive plan for the control of water pollution. The study was to determine the need for and the feasibility of a region-wide waste collection and disposal system, as well as to recommend other measures for maintenance of water quality.

After reviewing a number of proposals for the conduct of this study, the State Board selected, and in November 1966 entered into a contract with, Kaiser Engineers as Master Contractor for the study. The conclusions and the designs developed during that program were primarily concerned with the problems of biostimulation and toxicity. Because the objectives of the program did not include the conduct of research, additional follow-on studies were suggested for those two parameters.

Based on the recommendations of the 1966 Kaiser Study, the State Water Resources Control Board, in cooperation with the Department of Water Resources, the Department of Fish and Game, and the Sanitary Engineering Research Laboratory at Richmond, designed and implemented a study to evaluate the parameter of toxicity with a minor amount of effort on biostimulation. The results of the study are presented in this report.

Volume I presents a summary of the entire investigation as well as the general conclusions and recommendations resulting therefrom. Volumes II through VIII contain investigatory findings of discrete portions of the work. All volumes are available from the California Department of General Services.

The conclusions and recommendations are those of the research contractor and do not necessarily reflect the opinions or policies of the State Water Resources Control Board. This report is publication No. 44, Volume VII, in a series of water quality publications of the State Water Resources Control Board.

This project has been supported and financed in part by the Environmental Protection Agency under the Federal Water Pollution Control Act.

TABLE OF CONTENTS

I.	INTRODUCTION	1
	Study Objectives	1
	Background	1
	The Concept of Diversity	3
	Study Plan	5
II.	METHODS	7
	Site Selection	7
	Field Sampling	8
	Artificial Substrates	9
	Data Analysis	11
	Chemical Analysis	11
III.	RESULTS	14
	Standard Oil	14
	Mountain Copper	21
	San Leandro	24
	October 1970	24
	Offshore Area	26
	Cove Area	30
	Summary	34
	April 1971	34
	Summary	40
	Lower San Joaquin River	43
	September 1970	43
	March 1971	51
	South and Lower Bays	57

IV. DISCUSSION 63

Sampling Reliability 63

Diversity Indices as Indicators of Environmental Conditions 64

Relationships of Benthic Communities to Waste Toxicity 65

Individual Sites 65

Lower San Joaquin River 68

V. SUMMARY AND CONCLUSIONS 70

Individual Dispersion Zone Studies 71

Regional Studies 72

Benthic Invertebrates as Water Quality Indicators 72

VI. LITERATURE CITED 74

LIST OF FIGURES

Figure 1 - Artificial Substrate Sampler. 10

Figure 2 - Benthic Sample Station Locations Standard Oil Study Area. 15

Figure 3 - Relationship Between Diversity of Benthic Invertebrates and Waste Concentration at Standard Oil. 16

Figure 4 - Relationship Between Number of Benthic Invertebrates and Waste Concentration at Standard Oil. 17

Figure 5 - Relationship Between Numbers of Two Benthic Invertebrates and Waste Concentration at Standard Oil. 19

Figure 6 - Mountain Copper Benthic Sampling Station Locations. 22

Figure 7 - Number of Benthic Invertebrates from Samples in the Mountain Copper Area. 23

Figure 8 - Benthic Sample Station Locations, San Leandro Study Area. 25

Figure 9 - Relationship Between Diversity of Benthic Invertebrates and Waste Concentration at San Leandro Offshore Area, October 1970. 27

Figure 10 - Relationship Between Number of Benthic Invertebrates and Waste Concentration at San Leandro Offshore Area, October 1970. 28

Figure 11 - Relationship Between Diversity of Benthic Invertebrates and Waste Concentration at San Leandro Cove Area, October 1970. 29

Figure 12 - Relationship Between Number of Benthic Invertebrates and Waste Concentration at San Leandro Cove Area, October 1970. 31

Figure 13 - Relationship Between Waste Concentration and Numbers of Ampelisca at San Leandro Cove Area, October 1971. 32

Figure 14 - Relationship Between Waste Concentration and Diversity With Ampelisca Excluded from Calculation of D.I. at San Leandro Cove Area, October 1970. 33

Figure 15 - Relationship Between Diversity of Benthic Invertebrates and Waste Concentration at San Leandro Cove Area, April 1971. 35

Figure 16 - Relationship Between Number of Benthic Invertebrates and Waste Concentration at San Leandro Cove Area, April 1971. 36

Figure 17 - Relationship Between Waste Concentration and Numbers of Ampelisca at San Leandro Cove Area, April 1971. 37

Figure 18 - Relationship Between Waste Concentration and Diversity With Ampelisca Excluded from Calculations of D.I. San Leandro Cove Area, April 1971. 38

Figure 19 - Diversity Indices Collected From Artificial Substrates For Stations at San Leandro Cove Area, April 1971. 41

Figure 20 - Number of Organisms Collected From Artificial Substrates For Stations at San Leandro Cove Area, April 1971. 42

Figure 21 - Estimated Relative Toxicity Concentrations Resulting From Waste Discharges in Pittsburg-Antioch Area. 45

Figure 22 - Benthic Invertebrates Diversity for Stations in the Lower San Joaquin River, September 1970. 46

Figure 23 - Number of Benthic Invertebrates for Stations in the Lower San Joaquin River, September 1970. 47

Figure 24 - Number of Corophium and Corbicula at Stations in the Lower San Joaquin River, September 1971. 48

Figure 25 - Benthic Invertebrates Diversity Indices Based on Dry Weight Per Species in the Lower San Joaquin River, September 1971. 50

Figure 26 - Electrical Conductivity for Stations in the Lower San Joaquin River, September 1970. 52

Figure 27 - Benthic Invertebrate Diversity for Stations in the Lower San Joaquin River, March 1971. 54

Figure 28 - Number of Benthic Invertebrates for Stations in the Lower San Joaquin River, March 1971. 55

Figure 29 - Number of Corophium and Corbicula at Stations in the Lower San Joaquin River, March 1971. 56

Figure 30 - Benthic Invertebrates Diversity Indices Based on Dry Weight Per Species in the Lower San Joaquin River, March 1971. 58

Figure 31 - South Bay Benthic Sampling Station Locations. 59

Figure 32 - South Bay Benthic Sampling Station Locations. 60

Figure 33 - Number of Organisms at Stations in Lower and South San Francisco Bay for Samples Collected in April 1971. 61

LIST OF TABLES

Table 1. Observed Bottom Water Temperatures at High and Low Tide in the Standard Oil-San Pablo Sanitary District Study Area, January 8, 1971. 20

Table 2. Antioch Benthic Sample Station Locations. 44

ACKNOWLEDGEMENTS

This study was carried out by the California Department of Fish and Game under the general direction of Harold Chadwick. The field phases of the program were directed by Richard Wood. Dick A. Daniel had primary responsibility for collecting and processing invertebrate samples, analyzing results, and drafting this report.

Other participants in the Toxicity and Biostimulation Program, members of the Study Review Panel, and Dr. Perry L. McCarty made many constructive criticisms of the initial draft of this report.

We thank James Carlton of the California Academy of Sciences for reviewing the identification of some invertebrates and pointing out the impossibility of identifying many invertebrates accurately without more expert taxonomic help than was available during this study.

I. INTRODUCTION

The State Water Resources Control Board (SWRCB) has sponsored extensive research, monitoring and special studies to develop a better understanding of the effects of waste discharges on the environment of the San Francisco Bay-Delta system. In June of 1970, the SWRCB entered into an agreement with the California Departments of Water Resources and Fish and Game (DWR and DF&G) and the University of California to conduct a study of toxicity and biostimulation in San Francisco Bay-Delta waters. A facet of the study dealing with environmental effects of discharged wastes will be discussed in the following text. The only environmental effects of discharge wastes considered in this study were changes in benthic invertebrate communities.

STUDY OBJECTIVES

The objective of this phase of the study was to identify the effects of waste discharges on the benthic invertebrate communities occurring in the immediate area of discharges. A general relationsip was sought between the level of acute toxicity from a discharge and the degree of effect on the benthic invertebrate community. Such a relationship could serve as a basis for establishing waste discharge requirements.

BACKGROUND

Filice (1954a, 1954b, 1958, 1959) conducted several studies of the bottom faunas in the San Francisco Bay system. Several important general findings were made concerning the effects of wastes on the benthos. In studying a small portion of the estuary, Filice (1954a) found that:

> "(1) there is a marked decrease in both the number of animals present and the number of species on the bottom under heavily polluted water, and this decrease approaches zero as one nears the waste source;
>
> "(2) there is an increase in the volume of animals present, but no great increase in the species represented in areas marginal to the waste source;
>
> "(3) in normal waters the volume of living animals is again low but the number of species is relatively high in contrast to the other two areas."

Subsequent measurements of the biovolume of benthic communities throughout a major portion of the estuary led Filice (1954b) to conclude that his earlier conclusions concerning

biomass were generally applicable only to domestic waste discharges. Industrial discharges had greater adverse effects near the discharge and no stimulatory effect in marginal areas.

Filice's results support the hypothesis that environmental stress from pollution can influence species diversity. His study also emphasizes the need for data on bionumber, biovolume, and biomass as a corollary to diversity. In a later study, Filice (1959) found that natural variables other than salinity and bottom composition could generally be considered random with respect to his categories of pollution. He found no reason to believe that a natural variable would introduce a spurious regularity into the relationship between fauna and waste contamination.

While Filice's work identified general relationships between wastes and benthic communities, it was not designed to serve as a basis for quantitative management of water quality. The acute toxicities, the chemical characteristics, and the dispersion of wastes were not measured.

During the 1960's, the University of California Bay Study (UCBS) was conducted. This study was an extensive investigation of several aspects of the Bay ecosystem and waste discharges. The study area extended from Antioch downstream through San Francisco Bay, with different subsections of this area being sampled each year. A variety of physical, chemical and biological parameters were measured bimonthly. The biological parameters included the number and volume of each benthic invertebrate species, and species diversity was calculated.

The UCBS data on benthic invertebrates provided the principal environmental data used subsequently by the San Francisco Bay-Delta Water Quality Control Program in identifying environmental effects of waste loads (Kaiser Engineers, 1969). The Bay-Delta report concluded that a detectable depression in community diversity occurred in areas of San Francisco Bay where relative toxicity was not diluted by a factor of 25. On the basis of this evidence they proposed that relative toxicity be a primary management criterion for the discharge of toxic wastes to the Bay-Delta.

The relative toxicity of a waste was defined as the flow rate divided by the median tolerance limit expressed as a fraction. It thus becomes an estimate of the mass emission of toxicants.

The analysis by the Bay-Delta program provides substantial evidence that toxicity has important effects on the environment of the estuary and that the relative toxicity concept has considerable merit as a management approach. Nevertheless, valid questions remained unanswered, leading to the

conclusion that additional evaluation of toxicity was essential to water quality management in the Bay-Delta system.

One unanswered question, which was recognized by the Bay-Delta Program, resulted from the inherent inability of statistical procedures to determine the cause of identified relationships. While the Bay-Delta Program advanced substantial logic indicating that toxicity caused the observed relationship between waste concentration and diversity, other possible explanations could not be ruled out completely. The current study sought to identify the role of toxicity more definitively by selecting study sites where toxicity was the principal variable.

The application of relative toxicity in the Bay-Delta Program also has two implicit premises which were not evaluated. These are:

(a) All wastes having a given toxicity concentration, as measured by mortality in acute bioassays with fish, have the same biological effect at any given dilution, irregardless of the actual chemicals causing the toxicity.

(b) The total effect of toxicity at any point in the estuary is equal to the sum of the toxicities from each waste present at that location, even though each waste concentration may be well below lethal concentrations.

At best these premises are only approximately true, because it is well know that the physiological effects of different toxicants vary greatly. Nevertheless, the implicit assumption made during the Bay-Delta Program that these premises are close enough to being true that the concept is useful as a management tool may well be valid. The study described in this report was planned in part to test the first of these premises.

THE CONCEPT OF DIVERSITY

Diversity was an essential tool in the analyses made during the Bay-Delta Program, and it was used extensively in the current program also. Hence, a discussion of the concept of diversity is appropriate to provide a better basis for understanding both studies.

A natural biotic community is a complex unit of biotic and abiotic components which interact to produce a characteristic assemblage of organisms. Communities have many characteristics, and it is difficult to find one measure which describes the fundamental community structure and is indicative of a community's well-being.

The diversity of a community probably comes closest to being such a measure. The diversity of a community is the relationship between the number of individuals present and the number of species. "It is common observation that some areas support more kinds of organisms than others" (Connell and Orias, 1964).

Several theories have been advanced to explain differences in diversity (Pianka, 1966), but none provides a universal explanation. "Generally speaking, areas with more 'rigorous' environmental conditions have a lower diversity" (Connell and Orias, 1964). Also, "A marked environmental change without sufficient time for the evolution of a new community to occur is likely to lead to a reduction in the diversity of the community at the affected location" (Warren, 1971).

Pollution tends to both change the environment and make it more rigorous, so it is not surprising that diversity has been used in a variety of studies as a measure of the effect of pollution. In fact, Patrick (1953) defined pollution as "any thing which brings about a reduction in the diversity of aquatic life and eventually destroys the balance of life in a stream".

Several mathematical formulations have been proposed to quantify the diversity of an environment. Wilhm and Dorris (1968) evaluated the various indices on the basis of their utilization of the distribution of individuals among species, their relative independence of sample size and their being dimensionless. Wilhm and Dorris provide examples of the use of diversity indices based on information theory as biological indices of environmental change caused by waste effluents. Additional reviews on the use of diversity indices can be found in the works of Warren (1971), Patten (1962), and Pielou (1966). The mathematical basis behind the diversity index is explained in Volume 2 of this report.

In using diversity as a measure of pollution effect, one must keep in mind that there is no absolute scale for diversity values which would facilitate identifying such effects a priori. Rather, the normal diversity varies among habitats and groups of organisms, and furthermore, it often varies within an apparently uniform habitat in response to variations in some environmental condition. Hence, use of diversity as an indicator of pollution requires a careful evaluation of other environmental conditions.

Also, while a diversity index can be a very useful tool in the study of communities, other aspects, such as the distribution patterns of individual species, with all the ecological relationships this entails (Hutchinson, 1953), and population sizes are also important and must be considered in evaluating change in community structure. Indices should

not replace the use of other knowledge about the biology and environmental requirements of the species contributing to diversity (Warren, 1971).

STUDY PLAN

This phase of the current study was planned on the premise that cause and effect relationships between the waste discharges and benthic communities could be defined by studying individual waste dispersion zones selected to minimize variables other than toxicity. Within these zones it was expected that a gradient would exist from dramatic effects near the discharge to undetectable effects as waste concentrations approached background concentrations. It was recognized that background conditions might reflect some degradation, but it was expected that the waste dilution required for benthic communities to become similar to communities outside the dispersion zone would be a useful water quality management criterion.

The basic study approach was to select toxic waste discharges with definable dispersion zones and describe the natural benthic communities in the zone. The diversity, density, individual species distribution, and in some cases biomass of benthic invertebrates were then related to waste concentration and the acute toxicity of the waste. Discharges and dispersion zones were selected to minimize both extraneous environmental variables such as substrate type and adverse waste characteristics other than toxicity, so toxicity would be the principal variable affecting benthic invertebrates.

In addition to describing natural communities, benthic invertebrates colonizing artificial substrates were also enumerated.

As the study progressed, it became apparent that too few waste discharges with characteristics compatible with the study approach exist in the Bay-Delta system to permit full accomplishment of the study objectives. Therefore, the study plan was modified to include two broad areas where invertebrate communities were examined in relation to the combined effects of several wastes.

One of these broad areas was the lower reach of the San Joaquin River, where it was postulated that a gradient in toxicity would exist. This was expected because numerous wastes are discharged in the lower portion of the reach, while no discharges exist for a considerable distance upstream. The purpose was to determine whether benthic community characteristics were related to waste loading as described by the toxicity gradient.

The second area was San Francisco Bay from Hunter's Point to San Jose. The relationship between benthic diversity and toxicity postulated by the Bay-Delta Program was based on data from this reach. Samples were collected from the original UCBS stations in the reach to determine whether invertebrate communities had changed in the intervening years.

II. METHODS

SITE SELECTION

Criteria were developed to define an ideal study area. These were:

(1) A dispersion zone with a definable waste concentration gradient at least 1,000 feet long.

(2) Dissolved oxygen levels preferable above 5.0 mg/l throughout the dispersion zone.

(3) A discharge point located in less than 20 feet of water.

(4) A continuous waste effluent of predictable character.

(5) Geographical location of sites to be limited to the area between Richmond and Antioch.

(6) Reasonable accessibility by sampling craft.

(7) Ability to position dye injection equipment at an outfall point.

(8) Accessibility to a study area throughout a complete tidal cycle for dye sampling purposes.

A preliminary screening of discharges eliminated practically all of the discharges in the reach between Antioch and Richmond. Virtually all wastes there are discharged into the deeper portions of the main channel, where high dispersion rates essentially eliminate concentration gradients. Accordingly, discharges into other portions of the San Francisco Bay system were considered for study.

Studies were undertaken by the Department of Water Resources on the dispersion characteristics of several discharges in the bay and estuary. The results of these investigations are reported in Volume 4 of this report. In addition, Department of Fish and Game personnel collected and analyzed samples near each outfall to determine the suitability of benthic populations for study purposes.

The following discharges were rejected after either preliminary field survey or intensive evaluation idicated they did not meet sampling criteria:

	Site	Reason for Rejection
(1)	Petaluma River at Petaluma	Paucity of fauna apparently due to anaerobic conditions.
(2)	Steinberger Slough	Highly complex dispersion zone.
(3)	Union Sanitary District, Newark Plant	Dispersion zone contained less than 5.0 mg/l dissolved oxygen at low tide.
(4)	City of South San Francisco	Unacceptable dispersion characteristics.
(5)	Union Oil Refinery	Cooling water from Union Oil and PG&E powerplant made the dispersion zone difficult to identify and the waste apparently had low toxicity.
(6)	The waste treatment plants at Oro Loma and Hayward	Dispersion zone in intertidal area.

For our purposes the sewage treatment plant outfall of the City of San Leandro, waste outfalls of the Standard Oil Company and San Pablo Sanitation District at Richmond, and the site of previous operations of the Mountain Copper Company near the Martinez-Benicia Bridge were selected for study. In addition, the area studies were conducted in the San Joaquin River from the mouth of False River to New York Slough and in San Francisco Bay south of Hunter's Point.

FIELD SAMPLING

The basic sampling scheme was to establish stations throughout a waste dispersion zone so that the entire range of waste concentrations was sampled. Four replicate samples were collected at each station for analyses of the benthic community.

The benthic samples were taken with a Ponar grab, which samples an area of 23 x 23 cm and a volume of 6.4 liters. Any sample less than 6.4 liters was rejected.

For each sampling area, a particular substrate composition was selected based on preliminary sampling information. Each sample was inspected visually to determine whether its composition was the same as the standard. If it was not, the sample was rejected and another was collected. This procedure was followed to eliminate substrate composition as a variable affecting benthic invertebrates.

As grab samples were collected, they were immediately washed through a No. 30 (i.e., 0.59 mm clear opening) screen aboard the work boat. On some occasions this was not possible so the samples were put into plastic bags for washing at the laboratory. All material retained on the screen was placed in jars and preserved with formalin. Rose bengal dye was put into the formalin to aid in separating the animal material from plant debris.

In the laboratory all animals were picked from the sample, identified, and counted. In the case of broken specimens, primarily the worms, heads only were counted. In the case of the tubeficids where heads were not readily seen a standard length was used to determine when we had a single specimen. Dry weights for each species were determined for the Antioch samples. The animals were oven-dried for 48 hours at 350° F, cooled in a desiccator, and weighed.

Animals were identified by Fish and Game personnel. Identification to species and sometimes even to genus proved to be impossible for some animals. This resulted from there being no complete description of the invertebrate fauna in San Francisco Bay and the complexity in the taxonomy of some groups. As a result species sometimes had to be grouped to obtain a taxonomic unit which could be identified with confidence.

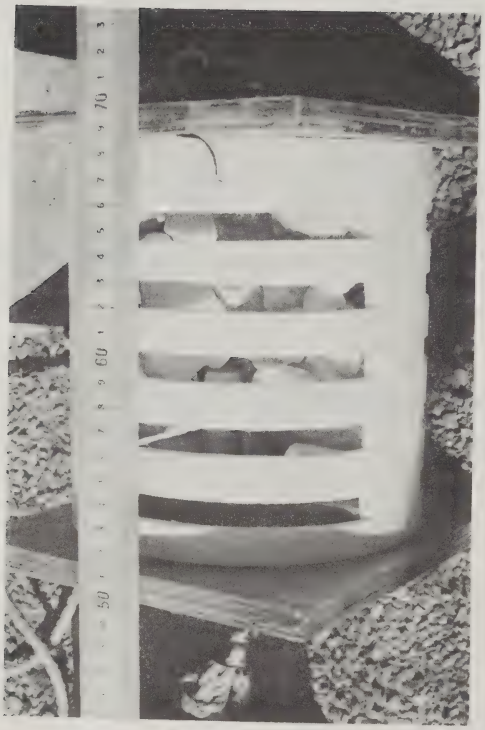
All invertebrate samples, except for those from the Lower San Joaquin River which were destroyed to measure dry weight, have been entered in the collection of the California Academy of Sciences.

ARTIFICIAL SUBSTRATES

Artificial substrates were placed in waste dispersion zones to collect invertebrates. The design of an acceptable artificial substrate sampler was reached after a good deal of trial and error experimentation. The wire baskets used by Mason, et al (1970) corroded too rapidly in brackish water. A unit made of paired plastic pipe cylinders was too large to suspend near the bottom. Also, animals colonized the connecting structure, making it apparent that it would not be feasible to treat the cylinders as replicates, as was originally intended.

The sampler which was found acceptable was a 7-inch cylinder made of 6-inch diameter, P.V.C. pipe (Figure 1). Slots 1/2-inch wide and 4 inches long were cut in the wall. The pipe was filled with 2-inch roofing rock and each end was plugged with a plywood disc. A 40-pound cement anchor was needed to hold the unit in place, as wave and tide action was substantial. A styrofoam float kept the substrate 2 feet off the bottom, and a retrieval line was run from the anchor to a second float.

Figure 1. Artificial Substrate Sampler



The samplers were left in the waste plume for three weeks. Two units were placed side by side to obtain replicate data. After the incubation period, the substrates were retrieved and the animals washed from the rocks and the substrate structure and preserved. The preserved animals were identified and counted in the laboratory.

DATA ANALYSIS

The principal analysis of the information collected from the benthic sampling was the calculation of diversity indices (DI). The equation used was derived from information theory by Margalef (1956). The equation is

$$DI = -\sum_{i=1}^{s} n_i/N \ (\log n_i/N)$$

where s is the number of species or otherwise recognizable taxonomic units. N the total number of organisms and n_i is the number of the i^{th} species or taxonomic unit. This equation has the advantage of being independent of sample size as well as being an expression of the compositional richness of a mixed-species aggregation of organisms.

This index of diversity possesses features which make it a reasonable descriptor of community structure. It is a dimensionless equation so numbers or biomass in any units may be used (Wilhm and Dorris, 1968).

As a result of the grouping of some species, the calculated diversity index is not a species diversity index, and it is generally lower than a species diversity index would be. The relationship between calculated diversity indices and true species diversity cannot be assumed to be constant. The trends, however, in the diversities reported in this report and trends based on diversities using tentative more specific identifications were very similar, hence it is reasonable to believe that the described relationships between diversity and environmental conditions are valid.

In addition to diversity, the density of organisms and the numbers of specific species were used to describe the relationship of benthic invertebrate communities to waste discharges.

CHEMICAL ANALYSIS

Grab samples of sediment were also collected from each station and sent to the Department of Water Resources Technical Services Laboratory at Bryte for chemical and mechanical analyses. The table below briefly outlines the analytical procedures used at Bryte.

Pesticides	Overnight extraction of wet sample with methanol and benzene, florisil cleanup, microcoulometric gas chromatographic detection.
Nitrate	Twenty-gram wet sample extracted with 100 ml deionized water for 1 hour in mechanical shaker. Nitrate determined by method in Envir. Sci. and Tech., vol. 1, no. 6, 1967, p. 488.
Ammonia and Organic Nitrogen	"Standard Methods for the Examination of Water and Wastewater", APHA publisher (N.Y., N.Y.) 1965, p. 533.
Organic Carbon	"Methods of Soil Analysis", ASA publisher, Madison, Wis., 1965, p. 1347.
Grease and Oil	"Standard Methods ...", p. 531.
Loss on Ignition	"Standard Methods ...", p. 535.
Total Mercury	Wet sample digested according to "Official Methods of Analysis of the AOAC", AOAC publisher, Wash., D. C., 1965, p. 375. Determined by atomic absorption method of Hatch and OTT, Anal. Chem., 40, 2085 (1968).
Total Metals	Ten-gram sample ashed in platinum dish overnight at 480°C. Metals dissolved in hot 6N HCL and analyzed by atomic absorption except arsenic which was determined by "Standard Methods ...", p. 56.
Available Metals	Ten-gram sample mixed with 100 ml deionized water. The pH adjusted to 4.5 with HCL. Rotated 24 hours in mechanical shaker and filtered and analyzed by atomic absorption except arsenic.
Biochemical Oxygen Demand	"Standard Methods ...", p. 406.

At the time of sampling, dissolved oxygen, temperature, electrical conductivity, pH and depth were recorded. Water samples for these measurements were collected just off the bottom. Whenever possible, sample stations were located within a waste dispersion zone to maintain the maximum constancy in regard to these parameters.

III. RESULTS

STANDARD OIL

The Standard Oil Refinery releases about 110 million gallons of petrochemical waste water into San Pablo Bay daily. Bioassays indicate a mean 96-hour TL_{50} of 80.5% waste for stickleback (Volume 3 of this report). The distribution of this waste into the receiving waters was characterized using the Army Corps of Engineers' model of San Francisco Bay. Dye injections into the model provided the waste concentration contours drawn in Figure 2. A detailed account of the waste dispersion studies is included in Volume 5 of this report.

In addition to Standard Oil wastes, the receiving water in this area receives about 10 million gallons daily from the San Pablo Sanitation District sewage treatment plant. The 96-hour mean TL_{50} of the unchlorinated waste for stickleback was 65% (Volume 3). The rate of flow and the TL_{50} indicate that the San Pablo sewage treatment plant contributes about 10% of the total relative toxicity discharged in the study area (Volume 3, Table 20). This is an underestimate as chlorination presumably increases toxicity of the San Pablo effluent by an undetermined amount.

The dispersion of San Pablo waste was not investigated and is not included in waste concentrations reported in Figure 2. Presumably this waste was dispersed by tidal action in a pattern similar to that determined for Standard Oil wastes. Therefore, we assumed that the concentration of San Pablo waste was about one-tenth that of the measured Standard Oil effluent concentrations, except at Stations 3 and 4 (Figure 2), which are immediately adjacent to the two discharges. At these points, the proportionate concentration of waste was undoubtedly higher for the closer discharge (San Pablo for Station 3 and Standard Oil for Station 4).

The density of benthic invertebrates was relatively high, and there was an average of 2,197 animals per sample. A tabulation of the data collected for each sample and station is included in Appendix A-1.

Diversity indices for each station are plotted in Figure 3. Except for Station 1, which may be in another environment, the trend exhibited by the data indicates a reduction in diversity as waste content of the water increases. A similar although much less distinct relationship occurred with the number of animals per sample (Figure 4). Populations at Station 1 (0.3% waste) departed significantly from both trends, and the number of organisms at Station 3 (2.2% waste) deviated upward substantially from the trend.

FIGURE 2

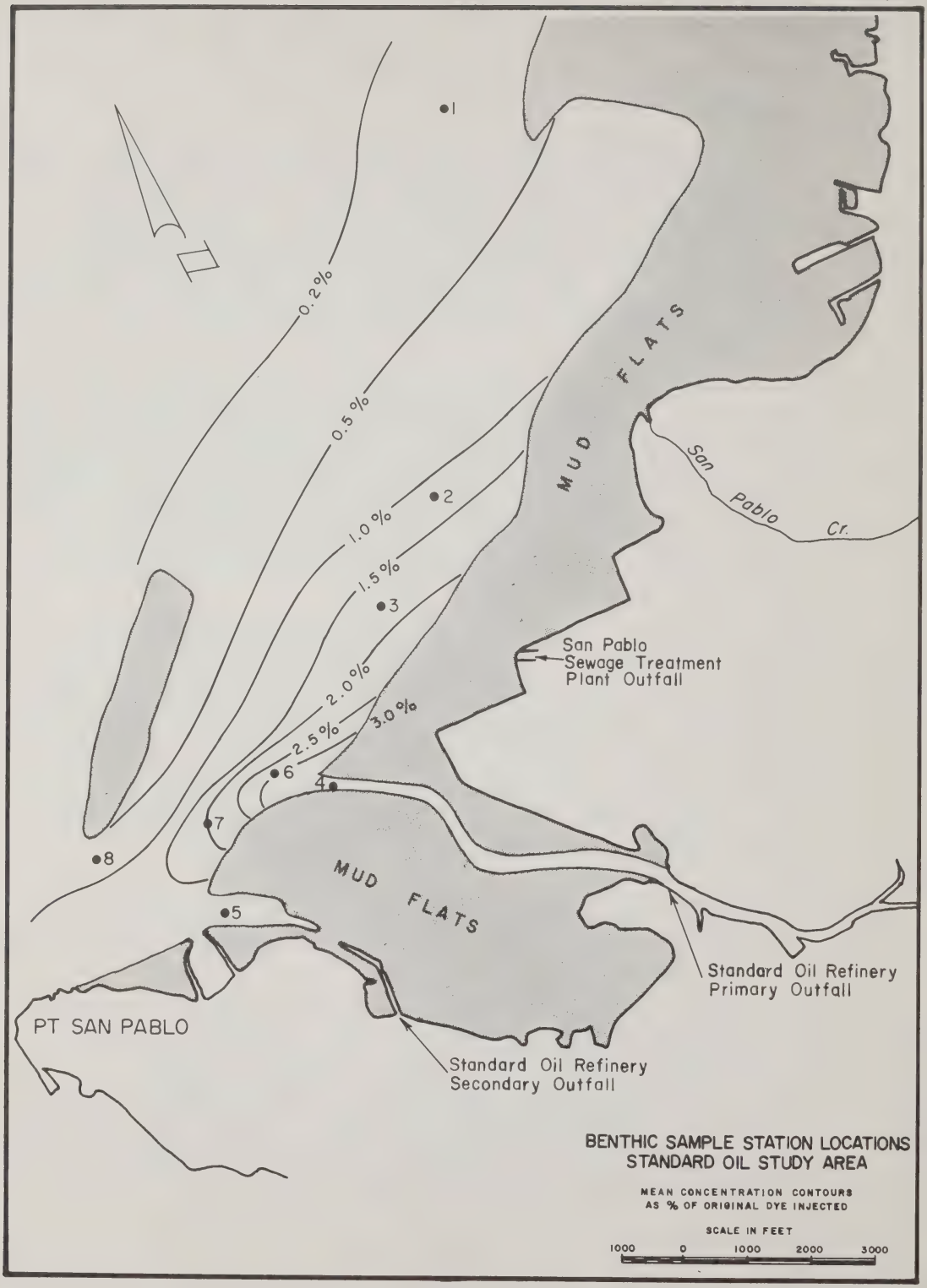

0.2%
0.5%
1.0%
1.5%
2.0%
2.5%
3.0%
1
2
3
4
5
6
7
8
MUD FLATS
MUD FLATS
San Pablo Cr.
San Pablo
Sewage Treatment
Plant Outfall
Standard Oil Refinery
Primary Outfall
Standard Oil Refinery
Secondary Outfall
PT SAN PABLO
BENTHIC SAMPLE STATION LOCATIONS
STANDARD OIL STUDY AREA
MEAN CONCENTRATION CONTOURS
AS % OF ORIGINAL DYE INJECTED
SCALE IN FEET
1000 0 1000 2000 3000

FIGURE 3

RELATIONSHIP BETWEEN DIVERSITY OF BENTHIC INVERTEBRATES AND WASTE CONCENTRATION AT STANDARD OIL

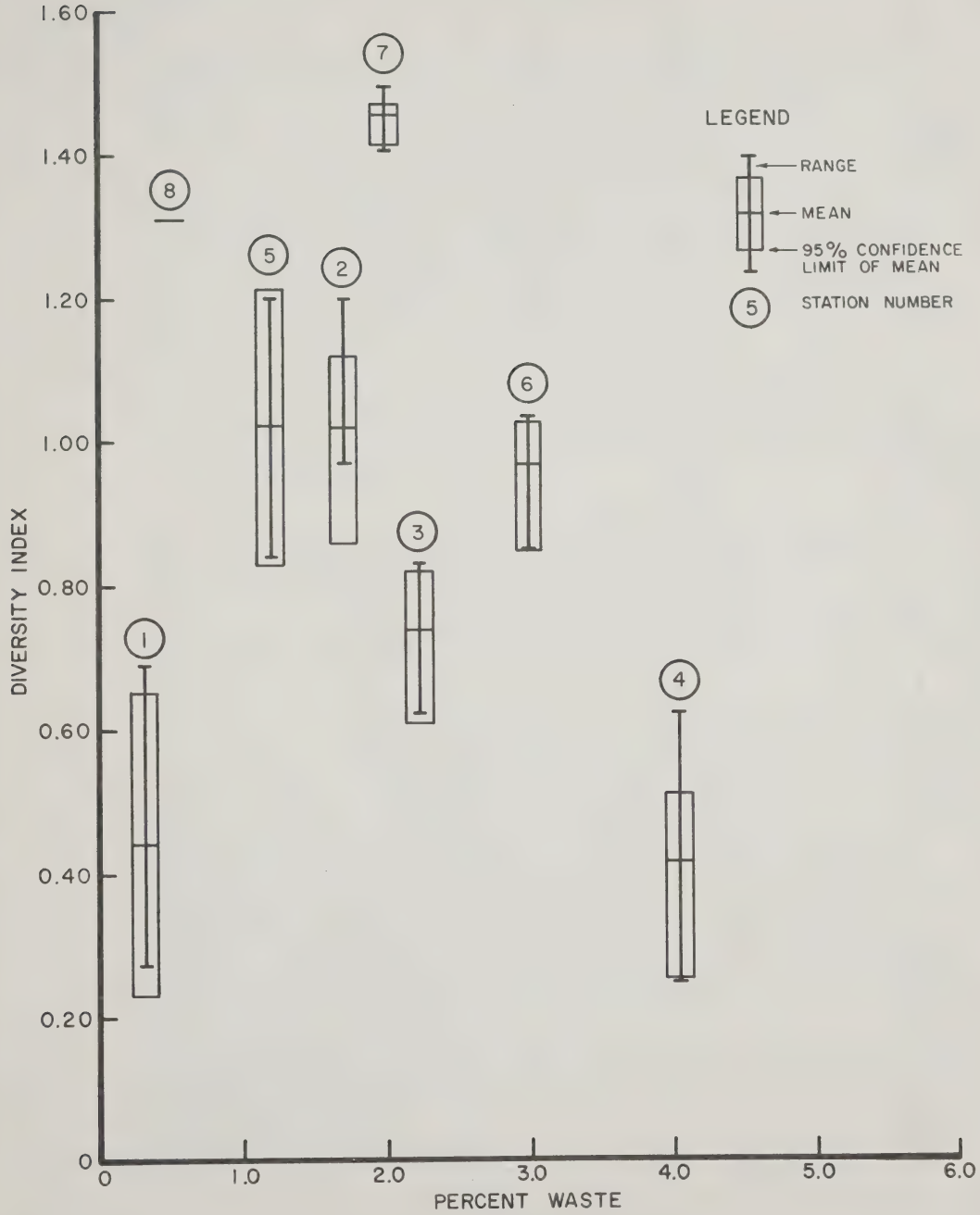
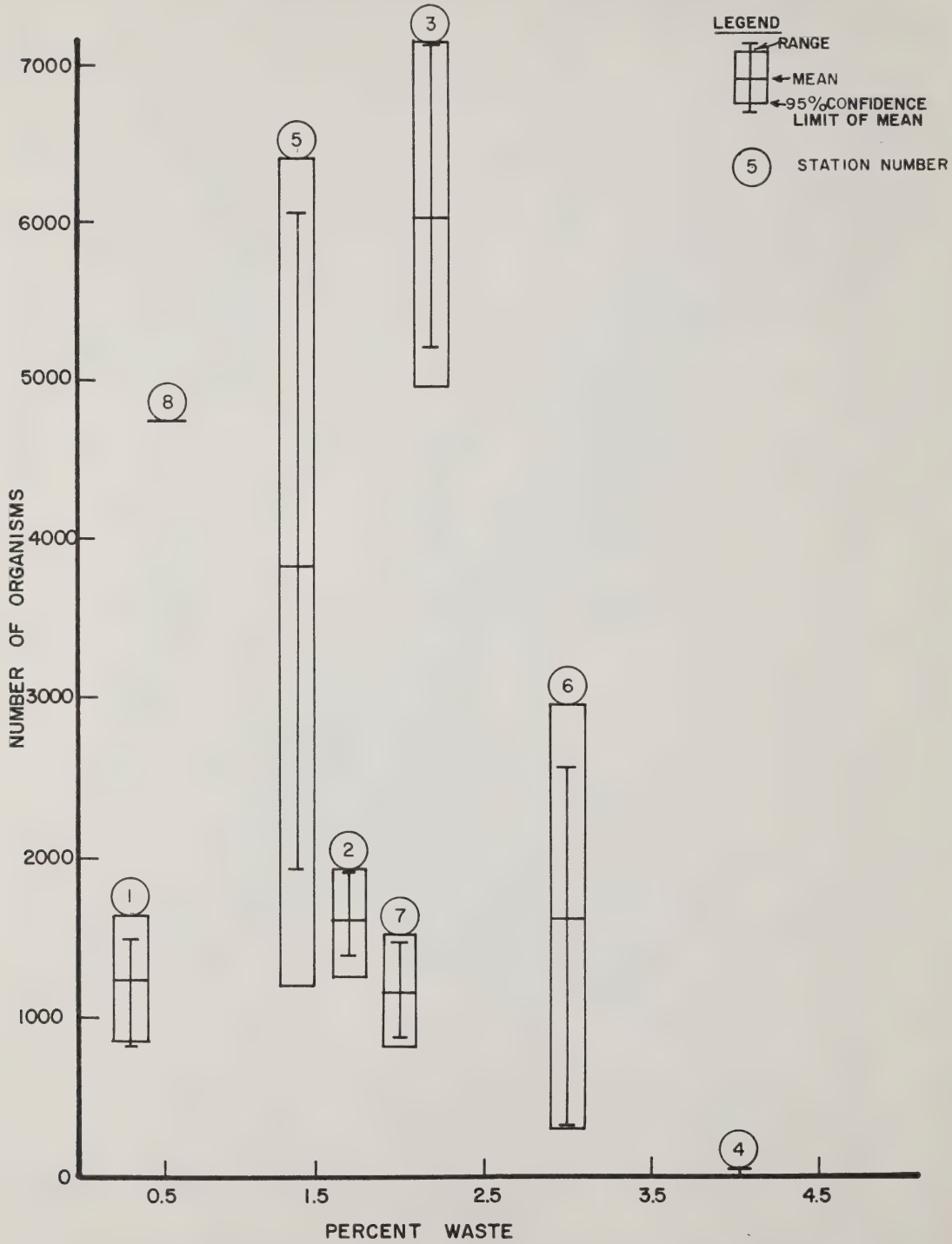


FIGURE 4

RELATIONSHIP BETWEEN NUMBER OF BENTHIC INVERTEBRATES AND WASTE CONCENTRATION AT STANDARD OIL.



Two invertebrate species, Streblospio benedicti, a polychaete worm, and Gemma gemma, a clam, were the dominant animals (Figure 5). The total of these species was largely responsible for the observed trend in numbers, with large numbers of S. benedicti being responsible for the deviation from the number-waste concentration relationship at Station 3.

Interpretation and clarification of the trends mentioned above requires analyses of variables other than total waste concentration which may influence the distribution of the benthos. The mechanical analysis of the substrate, Appendix B-1, showed that the percentage of the soil retained in the finest screen used ranged from 71 to 84% at 6 of 7 stations, but was 57% at Station 6. (The sample for mechanical and chemical analysis at Station 8 was lost.) The sampling program was designed to eliminate substrate composition as a variable. On the basis of the measured substrate composition, it is reasonable to assume that this was largely achieved, so the observed differences in benthic fauna are probably not due to substrate particle size.

The chemical analysis of the substrate is reported in Appendix C-1. None of the results correlate closely with estimated waste concentrations, although 7 of the 13 constituents measured were highest at Station 4, where waste concentrations were highest.

As mentioned above, Station 3 (2.2% waste) was close to the San Pablo sewage plant outfall. Very high numbers of the polychaete Streblospio benedicti and oligochaetes, an average of nearly 4,500 and 1,300 respectively were found in each sample. This may reflect an enrichment by the San Pablo waste, although the chemical analyses do not provide evidence of this.

Station 4 is in a small channel which leads directly from the holding pond for the Standard Oil waste water. A flood gate releases the waste water at low tide. Data collected prior to the benthic sampling indicate that the dissolved oxygen at this station dropped as low as 0.28 mg/l at low tide. This, coupled with a relatively high temperature at low tide (14.9 to 16.1 C), undoubtedly explains much of the low density and diversity of invertebrates at Station 4. This situation, although directly related to the presence of Standard Oil waste, must be considered as an effect from sources in addition to toxicity measured by the bioassay. The relative importance of oxygen, temperature and toxicity cannot be evaluated with the available data.

Except at Station 4, dissolved oxygen concentrations were greater than 6 mg/l, so they were probably not a significant factor.

FIGURE 5
RELATIONSHIP BETWEEN NUMBERS OF TWO BENTHIC INVERTEBRATES AND WASTE CONCENTRATION AT STANDARD OIL

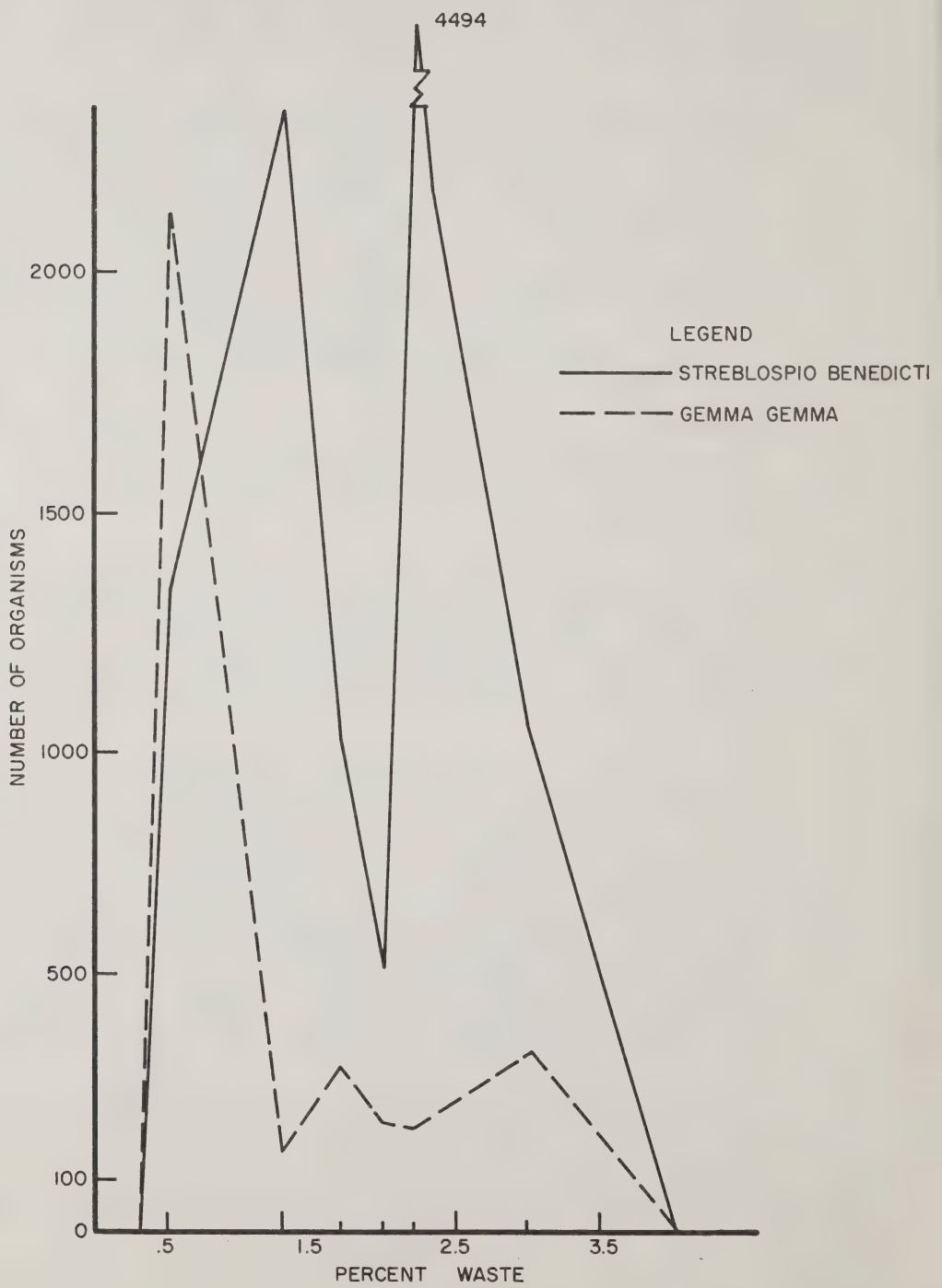


TABLE 1

OBSERVED BOTTOM WATER TEMPERATURES
AT HIGH AND LOW TIDE IN THE
STANDARD OIL-SAN PABLO SANITARY DISTRICT STUDY AREA
JANUARY 8, 1971

Station	Water Temperature (°C)	
	High Tide	Low Tide
1	7.5	--
2	8.4	8.1
3	7.8	9.4
4	14.9	16.1
5	7.9	10.9
6	8.6	8.3
7	8.7	10.0
8	8.1	8.6

Temperatures were elevated at Stations 2 through 8, so they were a potential factor influencing benthos (Table 1). Temperatures were most likely to have an effect at Station 4 where they were about 7°C over ambient, and at Station 5 where the range during the tidal cycle was 3°C. The Temperature range was also over a degree at Stations 3 and 7, but at other stations the elevation and range were small.

Temperatures are not closely correlated with waste concentrations, because they were also influenced by a secondary Standard Oil Company discharge of 6 mgd located near the head of the channel near Station 5. This discharge contained only cooling water and was presumably nontoxic. The trends in benthic diversity and numbers (Figures 3 and 4) do not appear to be influenced by either temperature elevation or range. The chief indication of this is Station 5 where benthic diversity and numbers were high despite the wide temperature range.

We have no satisfactory explanation for the low benthic diversity and numbers at Station 1. The concentrations of several metals, namely cadmium, copper, iron, and mercury, were

relatively high in comparison to the other stations and estimated waste concentrations. However, none of the concentrations are large in relation to some concentrations found in other areas studied where invertegrate populations were richer. None of the other parameters measured indicate any potentially significant differences.

In summary, benthic diversity and to a lesser extent numbers of benthic invertebrates were correlated inversely with waste concentration except at Station 1. At Station 4 a number of significant adverse conditions were identified. At other stations, the toxicity of waste offers the best explanation of the observed trends.

MOUNTAIN COPPER

Preliminary sampling at the Mountain Copper site indicated very high concentrations of heavy metals in the substrate. The source of these contaminants is believed to be slag piles left in the area from previous operations of the Mountain Copper Company. Leachate from the slag piles drains into a slough. This slough drains into Suisun Bay east of the Southern Pacific bridge. At times the leachate also drains directly into Suisun Bay west of the slough. It was assumed that the toxic waters flowing out of the slough would be dispersed both upstream and downstream in Suisun Bay by tidal action, and that concentration gradients could be established on the basis of the content of metals in the substrate.

It was decided to sample along a transect upstream from the slough, because the environment there was more uniform than downstream. Eight sampling stations were established leading from the slough to Point Edith, which is nearly 2 miles upstream (Figure 6). It was anticipated that heavy metal concentrations in sediments would reach background levels at Point Edith.

Figure 7 is a plot of the numbers of animals found in the benthic samples. The results of our faunal counts indicate that the sampling area was almost devoid of benthic invertegrates, except in the slough at Station 8, where oligochaetes were fairly numerous in the different type of habitat existing there. Appendix A-2 contains a tabulation of the organisms which were found. The diversity index is of no value in describing a community with so few organisms and was not calculated for these stations.

Heavy metal concentrations in the substrate were high and generally increased as one approached the slough. The arsenic content of the substrate increased from a relatively high amount, 24 mg/kg, at Point Edith to a peak of 67 mg/kg at Station 6. Cadmium ranged from 3.1 mg/kg in the slough down to 0.02 mg/kg at Point Edith (Station 1), while chromium

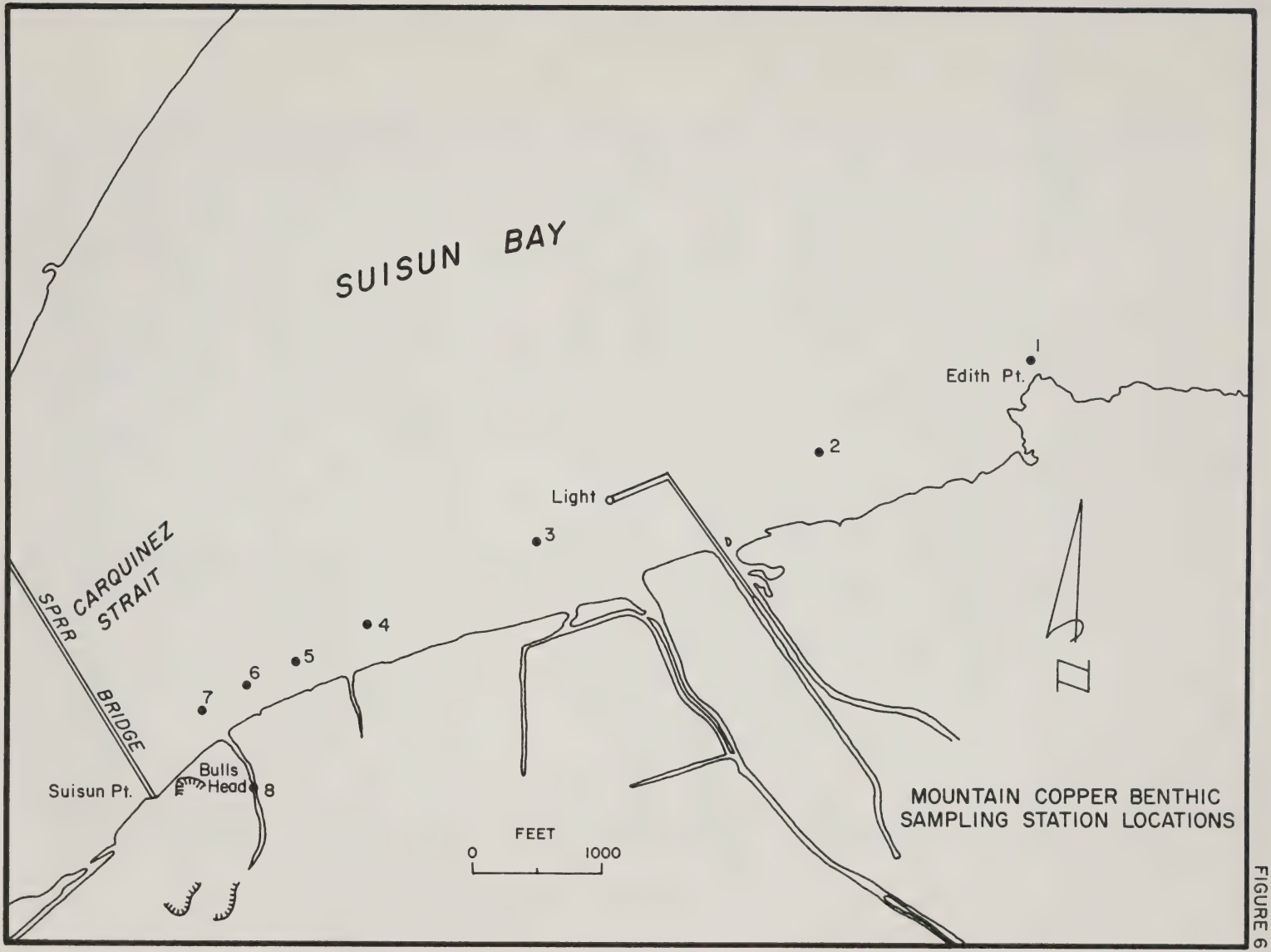
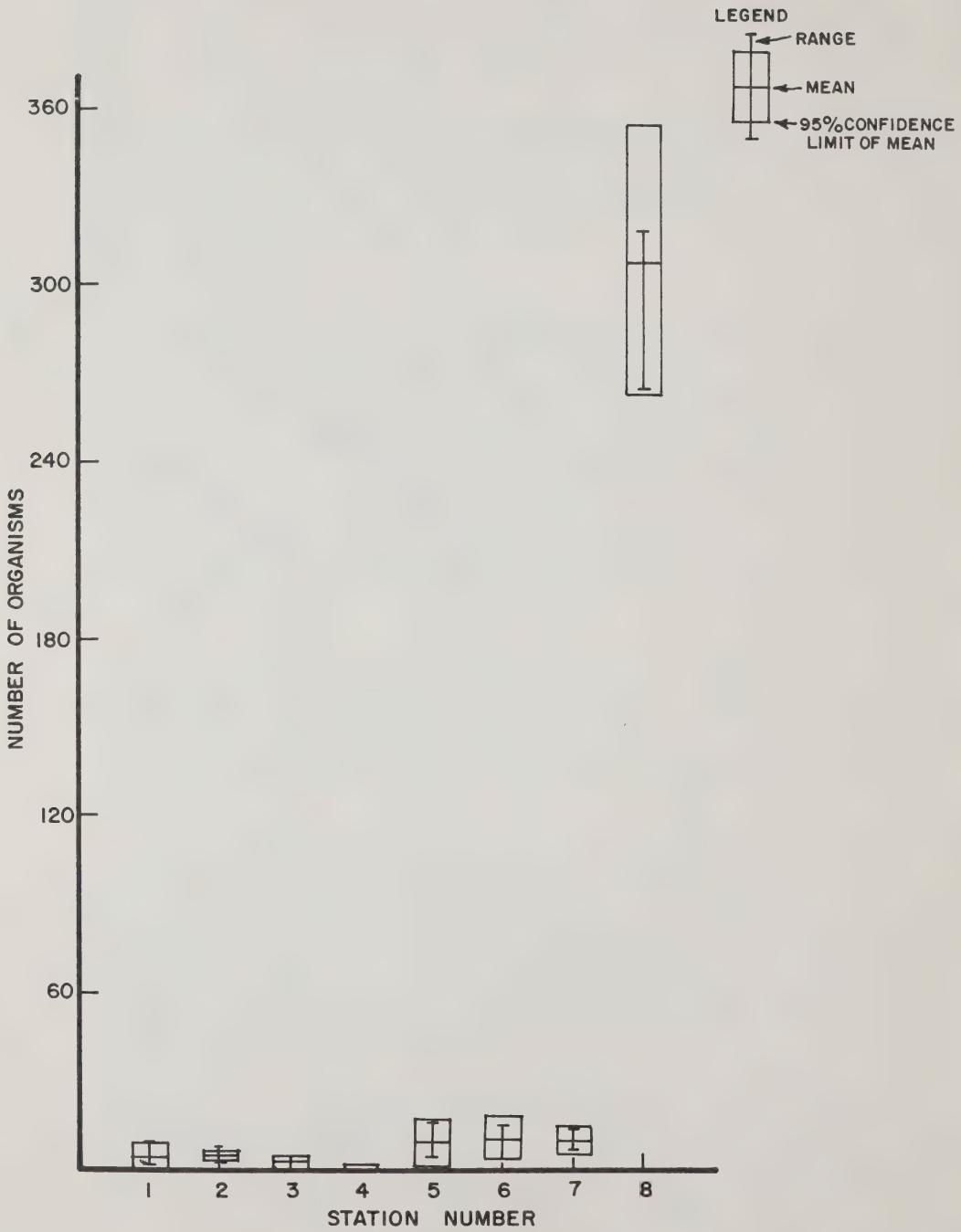

SUISUN BAY
Edith Pt.
1
2
Light
3
4
5
6
7
SPRR
CARQUINEZ
STRAIT
BRIDGE
Suisun Pt.
Bulls
Head
8
FEET
0
1000
MOUNTAIN COPPER BENTHIC
SAMPLING STATION LOCATIONS

FIGURE 6

FIGURE 7
NUMBER OF BENTHIC INVERTEBRATES FROM SAMPLES IN THE MOUNTAIN COPPER AREA.



ranged from 123 mg/kg to 16 mg/kg at the same stations. Iron also followed this trend, with the total concentration of iron in the slough being 37,000 mg/kg. Iron concentrations in the Bay were less than half of this and generally declined with distance from the slough, but the 7,350 mg/kg found near Point Edith is still a high concentration. Copper, lead, and zinc concentrations also increased approaching the slough. The concentrations of metals and other chemicals are listed in Appendix C-2.

Grease and oil were also measured in the substrate chemical analysis. Grease and oil concentrations were quite high (365-1,640 mg/kg) at all stations and unusually high (3,200 mg/kg) at Station 3. Station 3 was located near an oil loading dock which is presumed to be the source. Similar amounts of grease and oil were found in the Standard Oil study area and at a station on the San Joaquin River, where invertebrates were much more numerous. In light of this, it is assumed that grease and oils were not primarily responsible for the paucity of animals in this area.

The dissolved oxygen, pH, and chlorinity measured at the time of sampling did not vary significantly between stations nor were any of these parameters below acceptable levels.

Considering the lack of other obvious contaminants and the unusual concentrations of heavy metals, it seems probable that heavy metal concentrations were responsible for the paucity of benthic invertebrates. However, not enough is known about invertebrate requirements to be sure of this.

SAN LEANDRO

October 1970

In late October 1970, Department of Fish and Game biologists collected a series of benthic samples near the outfall of the San Leandro sewage treatment plant. In conjunction with this sampling, the Department of Water Resources carried out waste dispersion studies. Dye was released into the waste stream leaving the plant and later measured in the receiving water. A complete discussion of the waste dispersion studies is included in Volume 5 of this report. Contour lines of waste concentration are drawn in Figure 8.

When the study of this area was planned, it was anticipated that the waste dispersion zones for the Hayward, Oro Loma and San Leandro sewage treatment plants would overlap and be largely beyond the intertidal zone. Preliminary sampling had shown a uniform substrate in that region. The dye dispersion study, though, showed that wastes remained largely in the intertidal zone and streamed northward. The only sizable area not in the intertidal zone with waste concentrations high enough to meet study criteria for site selection

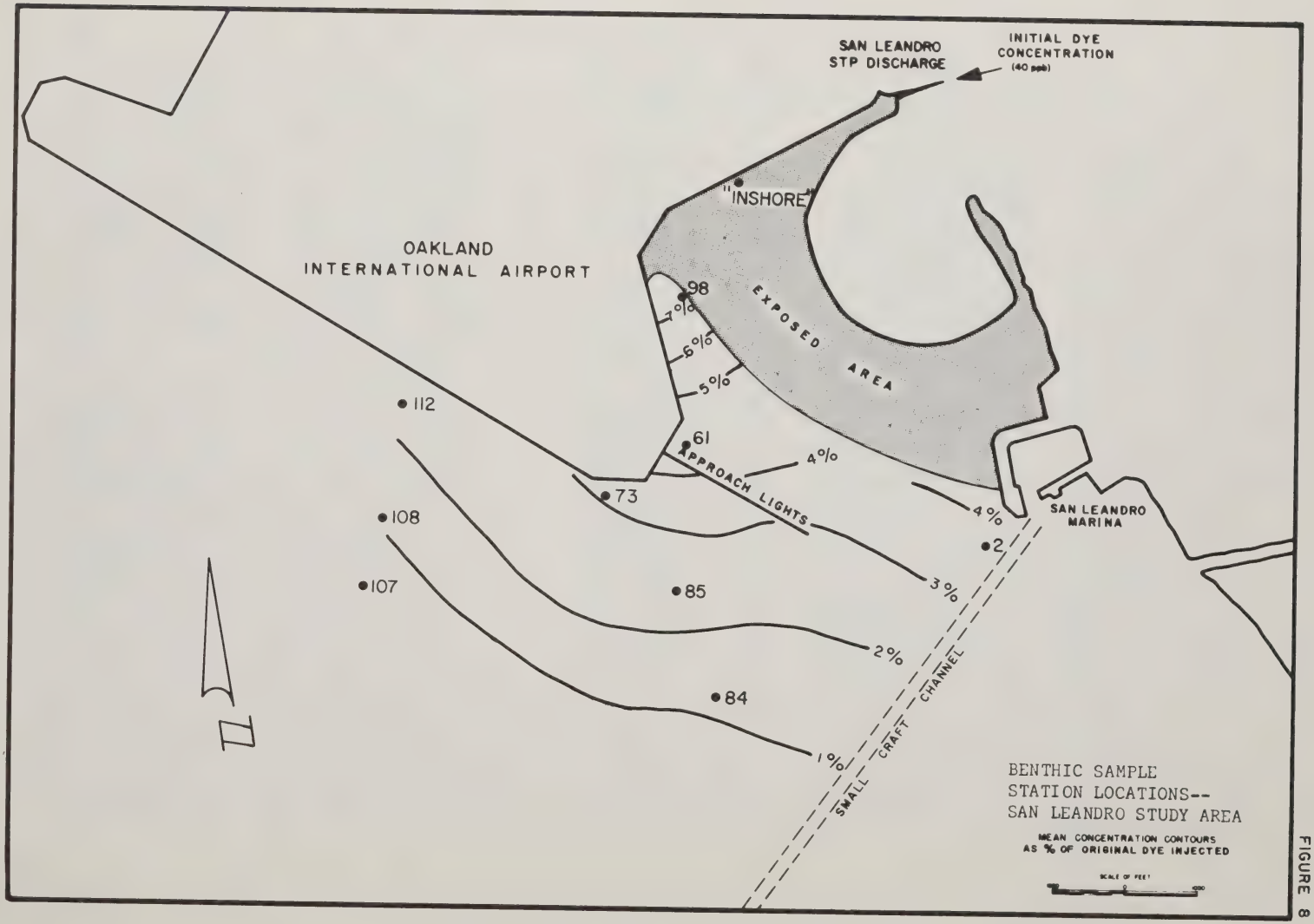

SAN LEANDRO
STP DISCHARGE
INITIAL DYE
CONCENTRATION
(40 ppb)
"INSHORE"
OAKLAND
INTERNATIONAL AIRPORT
98
7%
6%
5%
EXPOSED
AREA
112
61
4%
APPROACH LIGHTS
73
4%
SAN LEANDRO
MARINA
108
2
107
85
3%
2%
84
1%
SMALL CRAFT CHANNEL
BENTHIC SAMPLE
STATION LOCATIONS--
SAN LEANDRO STUDY AREA
MEAN CONCENTRATION CONTOURS
AS % OF ORIGINAL DYE INJECTED
SCALE OF FEET
0
500

FIGURE 8

was in the immediate vicinity of the San Leandro plant. Wastes in the receiving water there presumably are largely from the San Leandro treatment plant. This narrowed the scope of the receiving water evaluation considerably and forced it to be made in a less suitable study area.

The flow of waste from San Leandro ranges from 5-9 million gallons per day. A bioassay of chlorinated waste composited over 24 hours indicated a 96-hour TL_{50} of 44% for stickleback (Volume 3).

The benthic sampling stations (Figure 8) were located at points where DWR had made dye measurements and were selected to represent as wide a range of waste concentrations as possible. It was impossible to sample the benthos over the full range of waste concentration while maintaining a constant substrate type; consequently, two types of substrate were sampled.

Mechanical analysis of the sediment (Appendix B-3) defined the substrate types. Substrates at Stations 84, 112, and 108 had a large percentage of coarse material which was oyster shell rubble. The substrate at Station 107 was not analyzed but was similar. Stations 98, 61, 73, and 85 had substrates which were a fine silty mud. These significant differences made it necessary to treat these groups of stations separately in order to avoid bias. In this report those stations which were in the shell debris area will be designated as "offshore", and the stations in the region of the soft mud will be labeled "cove area".

Offshore Area. Appendix A-3 contains the data collected from the benthic samples. Figure 9 is a plot of the species diversity index values calculated for the offshore stations and plotted against percent waste. The mean diversity indices range from 0.95 to 1.55. It can be seen from this figure that standard errors overlap, so diversity indices do not differ significantly. The same situation holds true for the number of animals per sample (Figure 10).

The physical data collected along with the benthic samples indicate that dissolved oxygen, electrical conductivity, pH, and temperature were at levels which would not adversely affect the benthos. There was no significant difference between the stations with respect to any of these measurements.

Appendix C-3 contains the chemical analysis data for the sediment material. There is no indication that any of the properties measured occurred in sufficient amounts to affect the benthos. Chemical analysis was not performed on sediment from Station 107 (0% waste).

FIGURE 9

RELATIONSHIP BETWEEN DIVERSITY OF BENTHIC INVERTEBRATES AND WASTE CONCENTRATION AT SAN LEANDRO OFFSHORE AREA, OCTOBER 1970

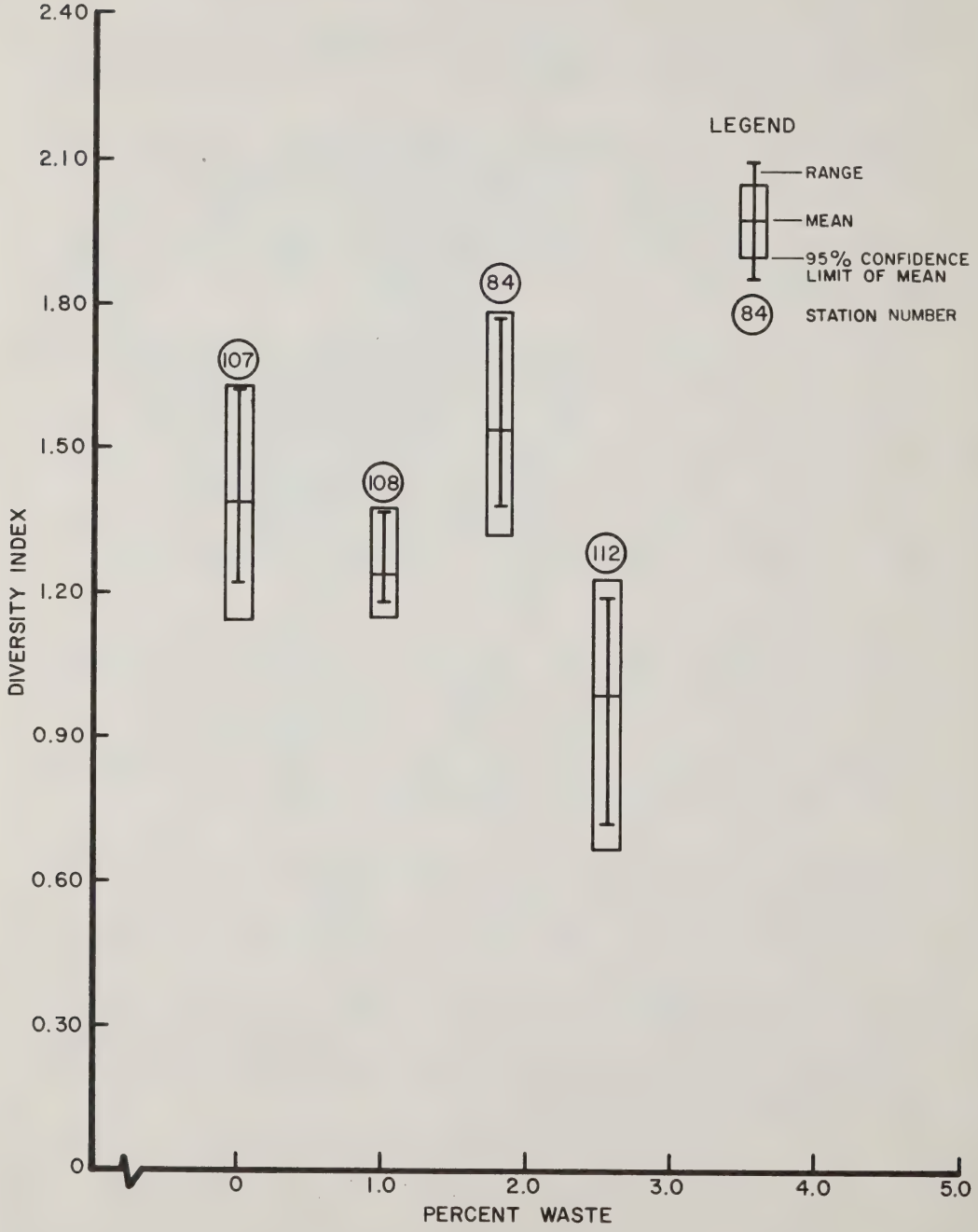
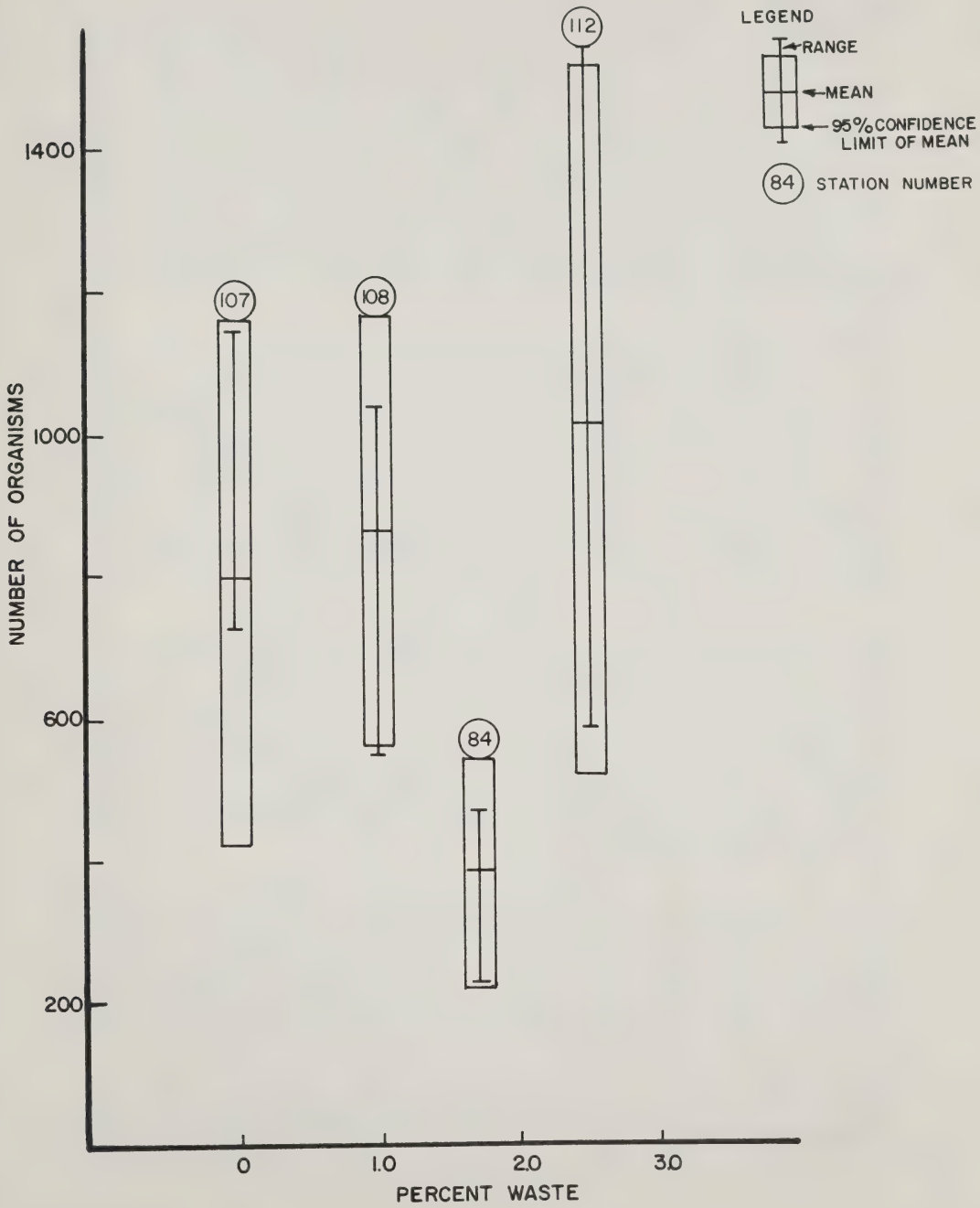


FIGURE 10
RELATIONSHIP BETWEEN NUMBER OF BENTHIC INVERTEBRATES AND WASTE CONCENTRATION AT SAN LEANDRO OFFSHORE AREA, OCTOBER 1970



The results presented above indicate that either the waste concentrations in the offshore area were below that which would produce response in the benthic community, or some unmeasured factor has masked the effect of the waste.

Cove Area. The data from the benthic samples taken in the cove area appear in Appendix A-3. There is a distinguishable trend in results. Figure 11 shows a direct relationship between waste concentration and diversity index. The diversity index values range from a mean of about 1.01 in 2.2% waste up to 1.61 in 7.2% waste. An analysis of variance showed that these means differed significantly. The number of animals found per sample shows an inverse relation between waste concentration and the number of animals (Figure 12). Most of this difference was between Station 85, which was in 2.2% waste and produced nearly 3,600 animals per 6.5 liter grab sample, and the other three stations which had mean numbers of animals ranging from less than 1,100 to about 1,500 per sample.

These findings can be explained partially by the distribution of the amphipod Ampelisca in relation to the waste concentrations. Figure 13 is a plot of the numbers of Ampelisca at the various waste concentrations. It is clear that there is an inverse relationship which accounts for a major portion of the trend in total numbers of animals. Omitting Ampelisca from calculations of diversity indices (Figure 14) makes differences among means no longer significant. This occurs largely because the variance is increased at individual stations. The direct relationship between mean diversity and waste concentration is changed little.

The sediment chemical analyses (Appendix C-3) indicate that the amounts of cadmium, chromium, copper, iron, zinc, and chlorinated hydrocarbons generally increased with increasing waste concentration in the receiving water. These concentrations may have been high enough to produce some degree of environmental stress with a resultant reduction in numbers, especially in the sample taken from 7.2% waste, but again not enough is known about tolerances of invertegrates to these constituents to permit conclusions as to which, if any, constituent had an effect.

The measurement of dissolved oxygen, pH, electrical conductivity and temperature done at the time of benthic sampling does not indicate any adverse conditions present at any station, nor was there any great difference between stations. As mentioned above, the bottom in the area is covered with a fine, silty mud. The samples had from 72% to 99% of the material passing through a No. 270 screen.

Variations in salinity during the tidal cycle may have influenced invertebrates, since a freshwater waste was being released in salt water. Salinity in receiving water samples

FIGURE 11

RELATIONSHIP BETWEEN DIVERSITY OF BENTHIC INVERTEBRATES AND WASTE CONCENTRATION AT SAN LEANDRO COVE AREA, OCTOBER 1970.

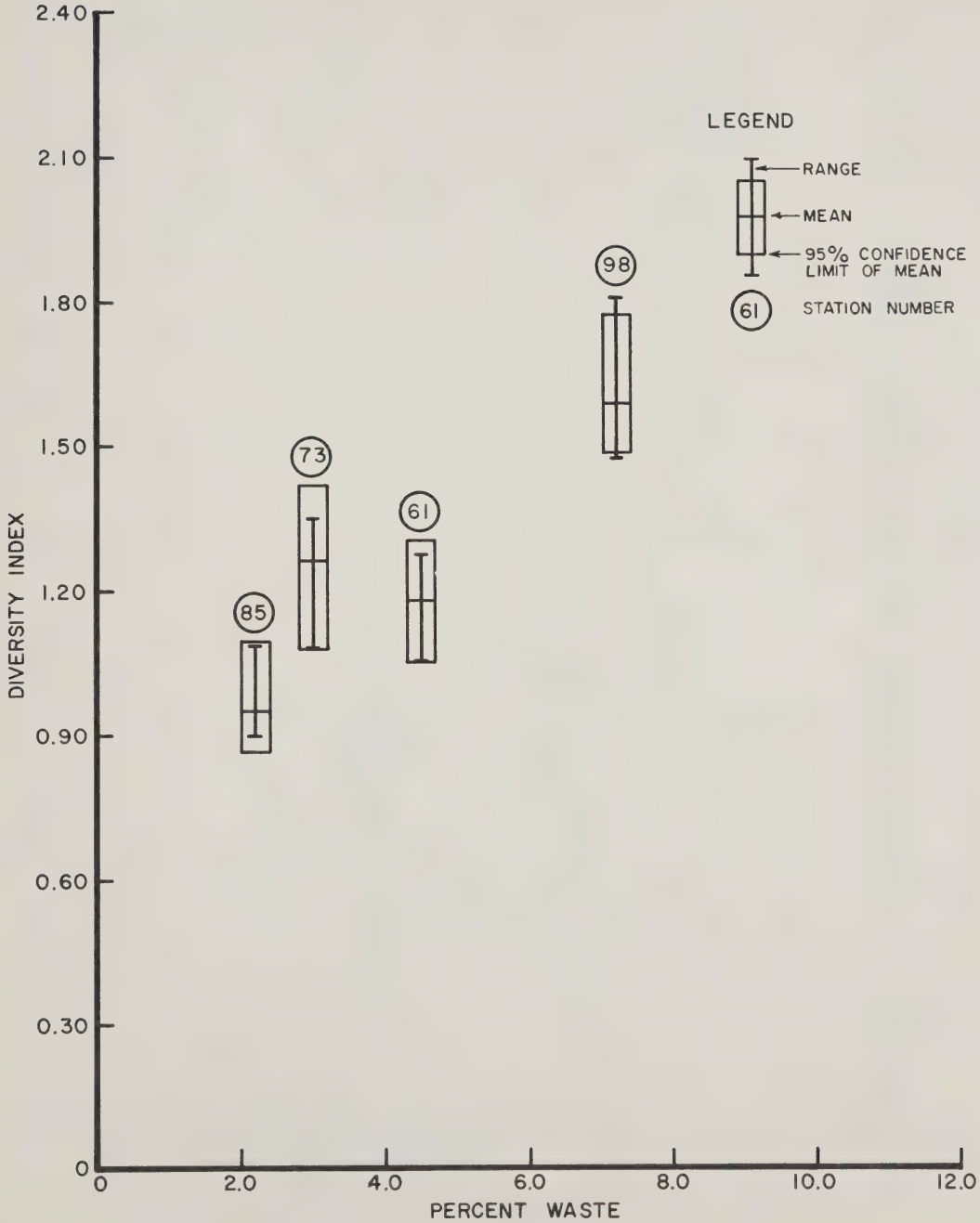


FIGURE 12
RELATIONSHIP BETWEEN NUMBER OF BENTHIC INVERTEBRATES AND WASTE CONCENTRATION AT SAN LEANDRO COVE AREA, OCTOBER 1970

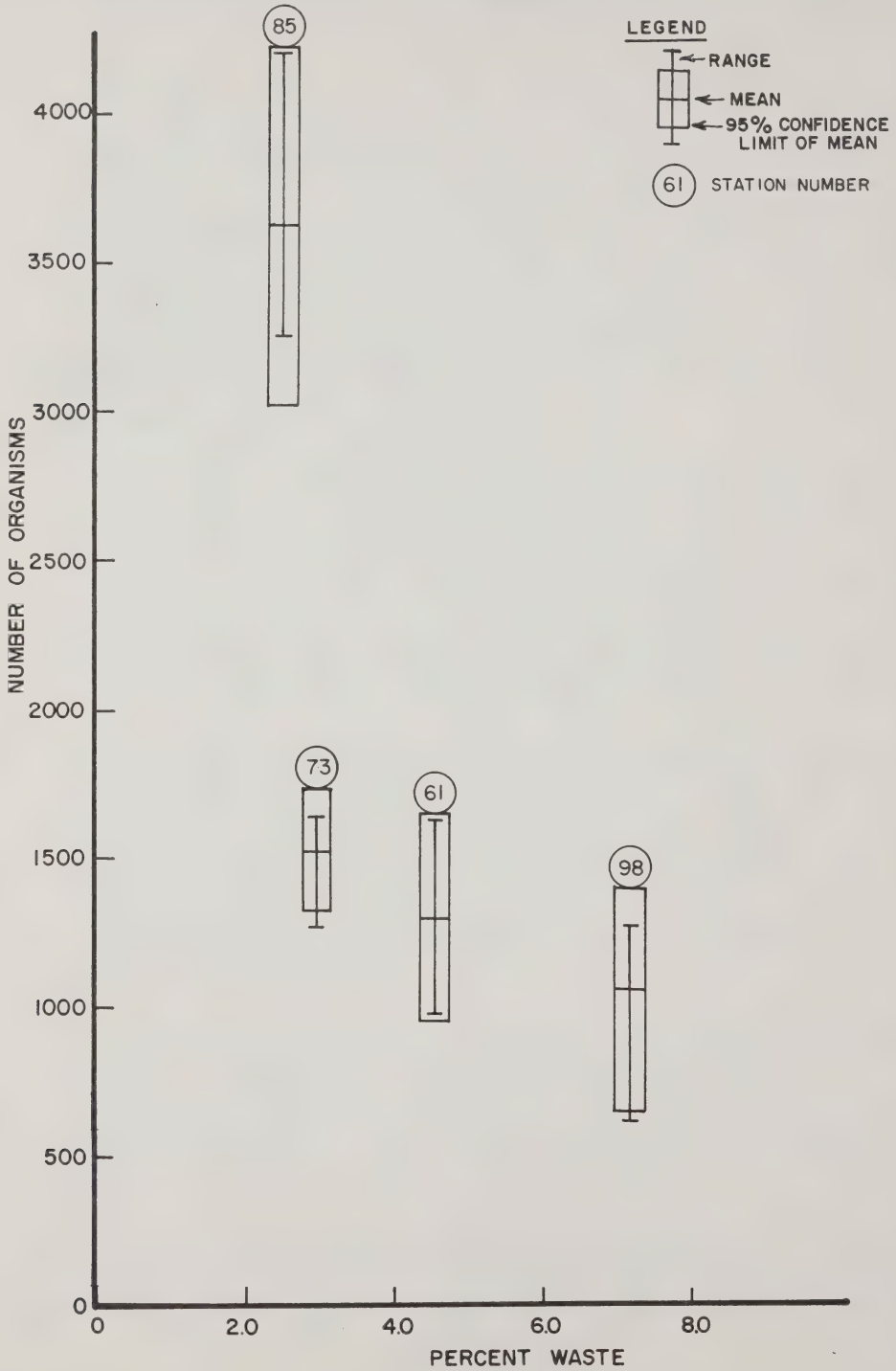


FIGURE 13
RELATIONSHIP BETWEEN WASTE CONCENTRATION AND NUMBERS OF AMPELISCA SP.
AT SAN LEANDRO COVE AREA, OCTOBER 1971

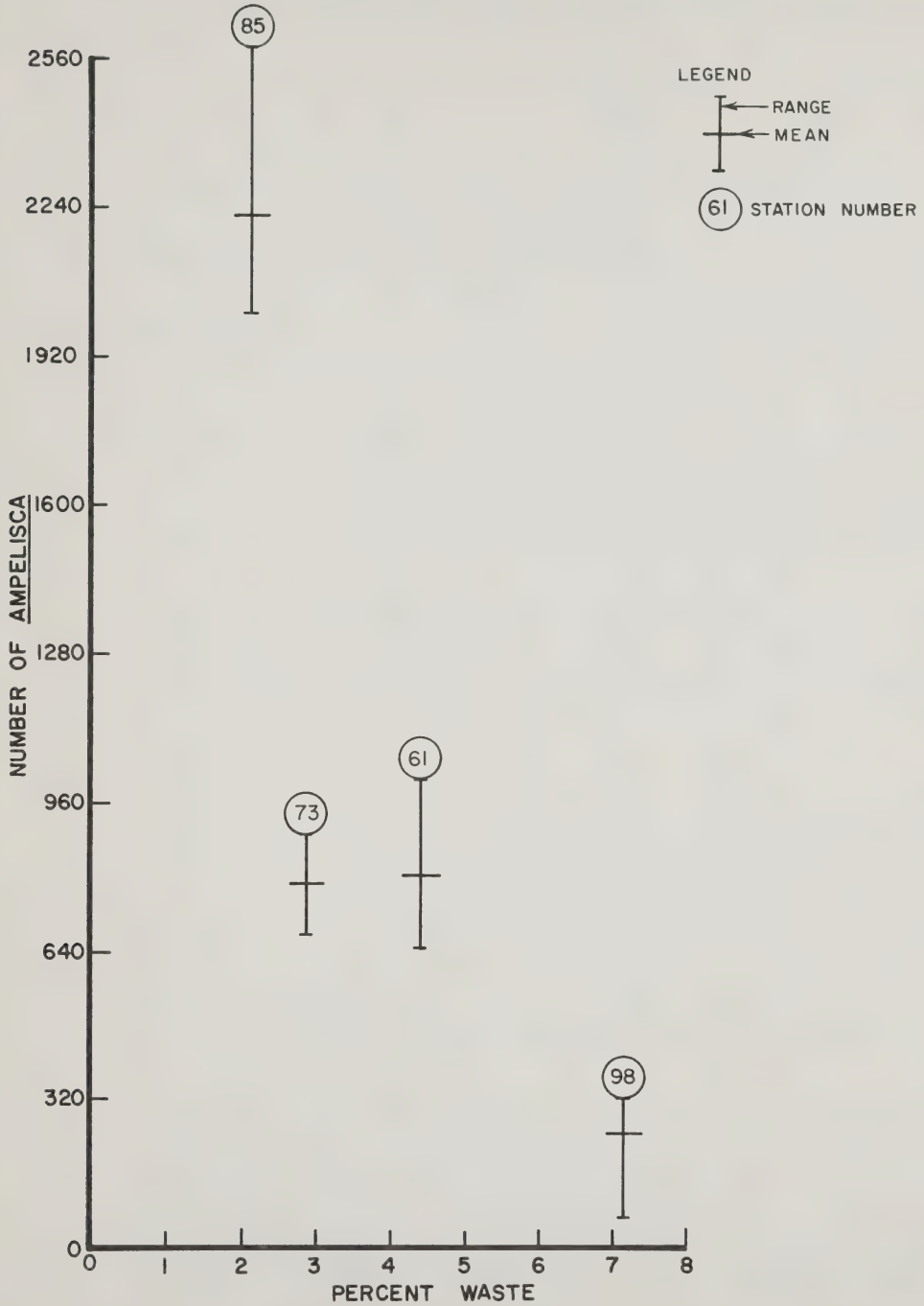
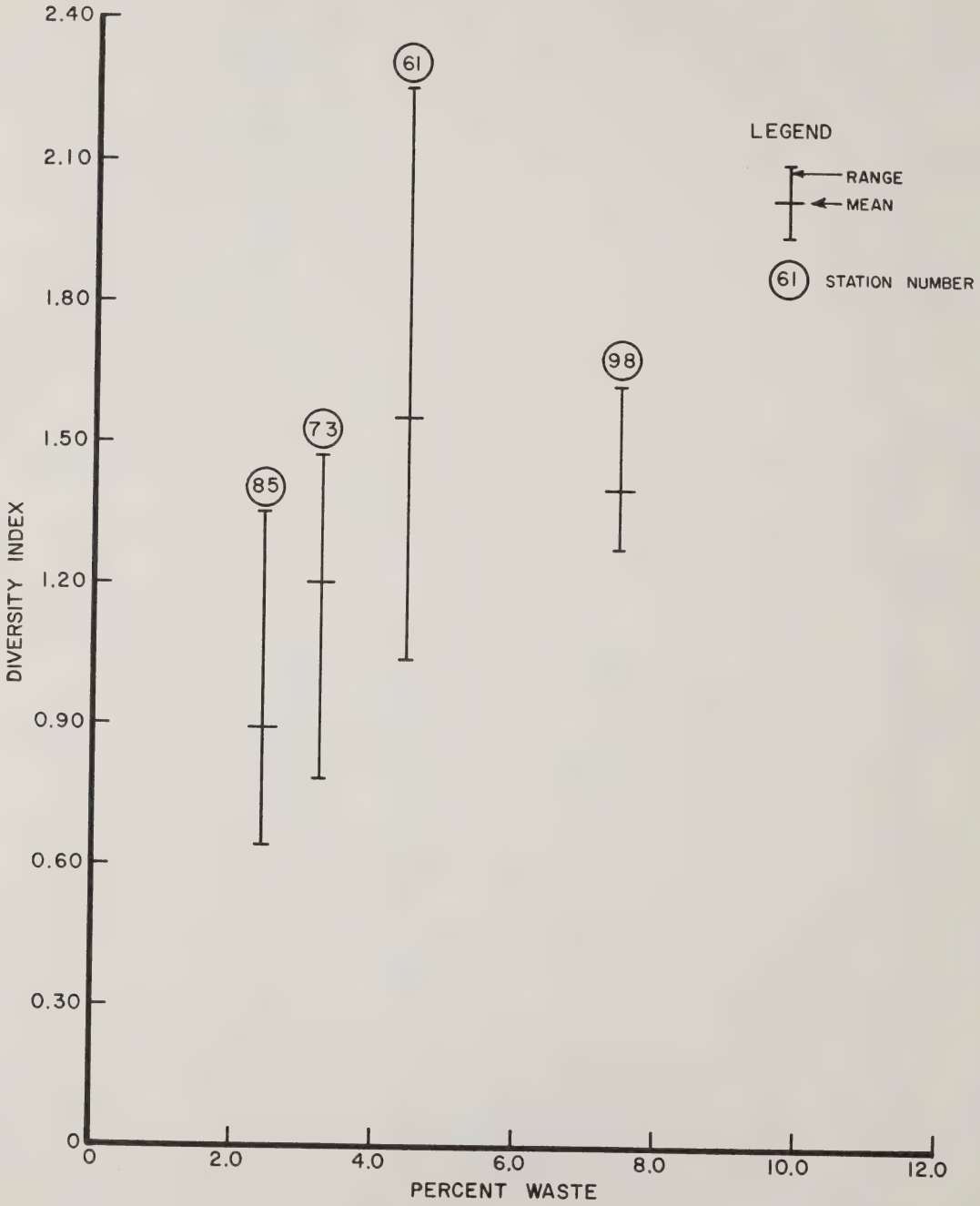


FIGURE 14

RELATIONSHIP BETWEEN WASTE CONCENTRATION AND DIVERSITY WITH AMPELISCA EXCLUDED FROM CALCULATION OF D.I. AT SAN LEANDRO COVE AREA, OCT. 1970



collected during the month prior to sampling averaged about 28 o/oo (Volume 3, Appendix B, Table 12). Waste concentrations at the innermost station (98) ranged from about 3.5 to 14% (Volume 5), indicating a salinity range of 24 to 27 o/oo during the tidal cycle. Considering natural variations expected in an estuary, this intuitively is judged too small to have much effect on the benthos.

Salinity tolerance has been described for relatively few of the species found. Felice (1958) found Ampelisca, the dominant invertebrate at San Leandro, at salinities down to 20 o/oo, and Painter (1966) found a similar salinity at their upstream limit of major abundance in late summer and fall. (Painter apparently identified Ampelisca as Photis californica.) The difference between the probable minimum salinity at San Leandro and the minimum tolerated by substantial Ampelisca populations makes it unlikely that the observed distribution was controlled by salinity.

Summary. A summary of our findings is that in the offshore area, where waste content of the receiving waters ranged from 2.5 to 0% waste, no effect on the benthos was observed. In the cove area, there is a direct relationship between diversity and waste concentration and an indirect relationship of numbers of animals per sample to waste concentration.

Only environmental parameters associated with waste concentration were found to be correlated with the observed distribution of benthos. The apparent lack of oxygen, salinity, and temperature effects make it probable that a toxic component of the waste was responsible for observed relationships.

April 1971

Benthic sampling was conducted in the San Leandro cove area for a second time in April of 1971. These studies were carried out in conjunction with investigations into the role of chlorination on the environmental effects of waste waters from the San Leandro sewage treatment plant. The stations occupied were the same as those in the cove area sampled the previous October. One additional station was sampled near the San Leandro Marina. It is labeled "2" on Figure 8. It was assumed that the distribution of the waste in the receiving water was sufficiently constant to warrant the use of the October data on dispersion.

The data collected from the benthic samples are presented in Appendix A-4. The diversity indices are presented in Figure 15. The trend exhibited in Figure 15 indicates that diversity tended to increase as the waste content increased. The opposite trend is suggested by the numbers of animals per sample (Figure 16), although differences among means are not significant. Thus, the April data indicate relationships between waste concentration and both diversity and numbers

FIGURE 15

RELATIONSHIP BETWEEN DIVERSITY OF BENTHIC INVERTEBRATES AND WASTE CONCENTRATION AT SAN LEANDRO COVE AREA, APRIL 1971

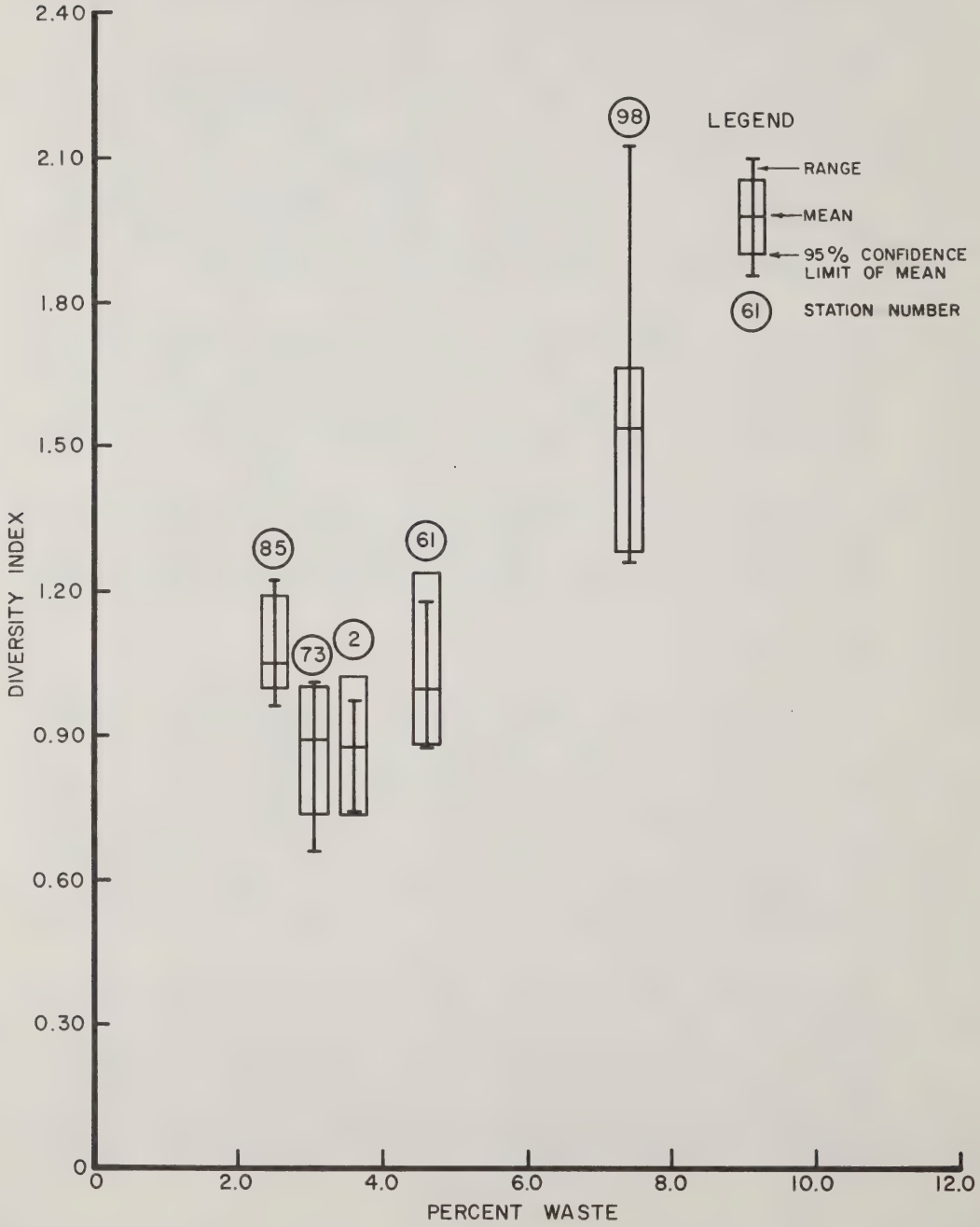


FIGURE 16
RELATIONSHIP BETWEEN NUMBER OF BENTHIC INVERTEBRATES AND WASTE CONCENTRATION AT SAN LEANDRO COVE AREA, APRIL 1971

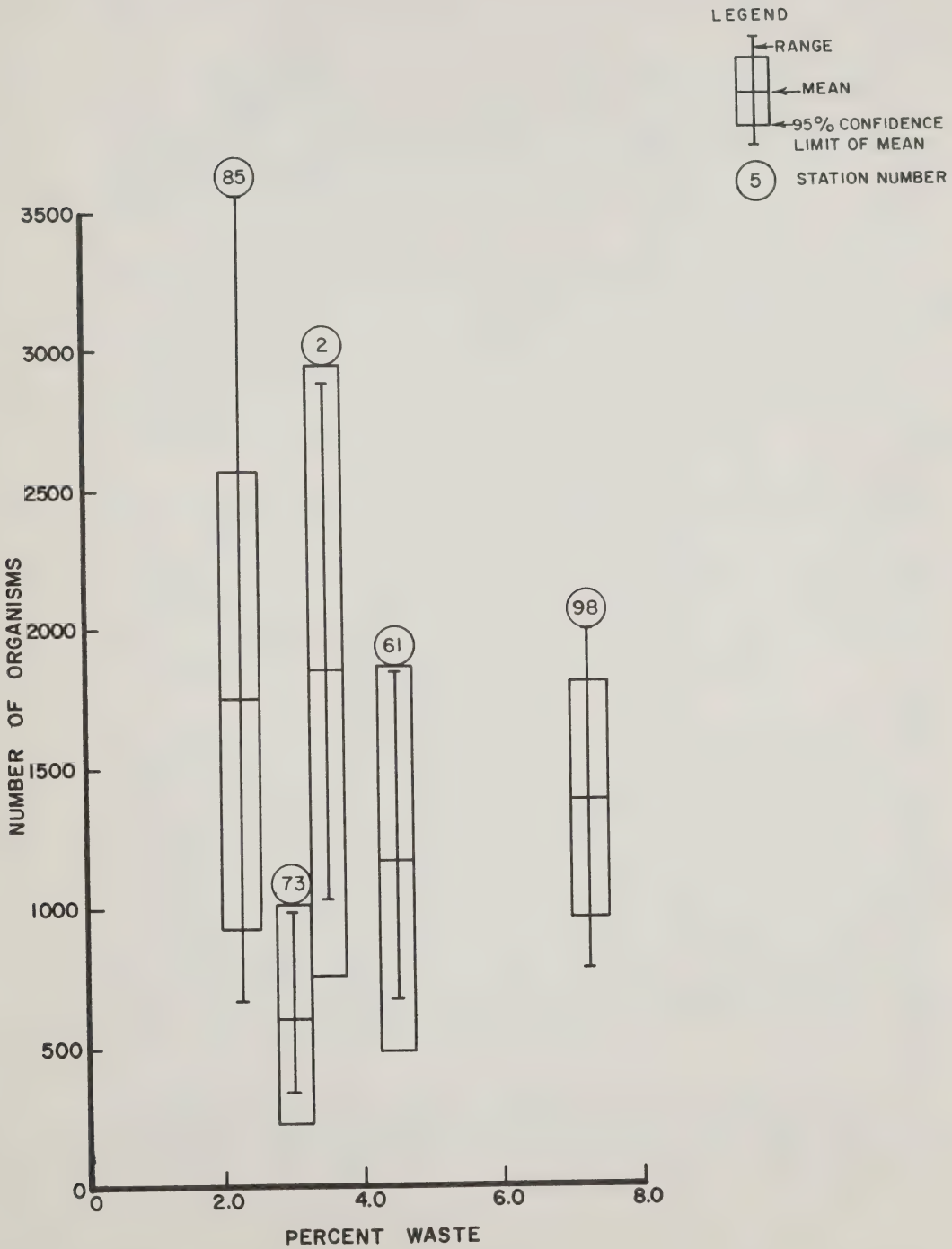
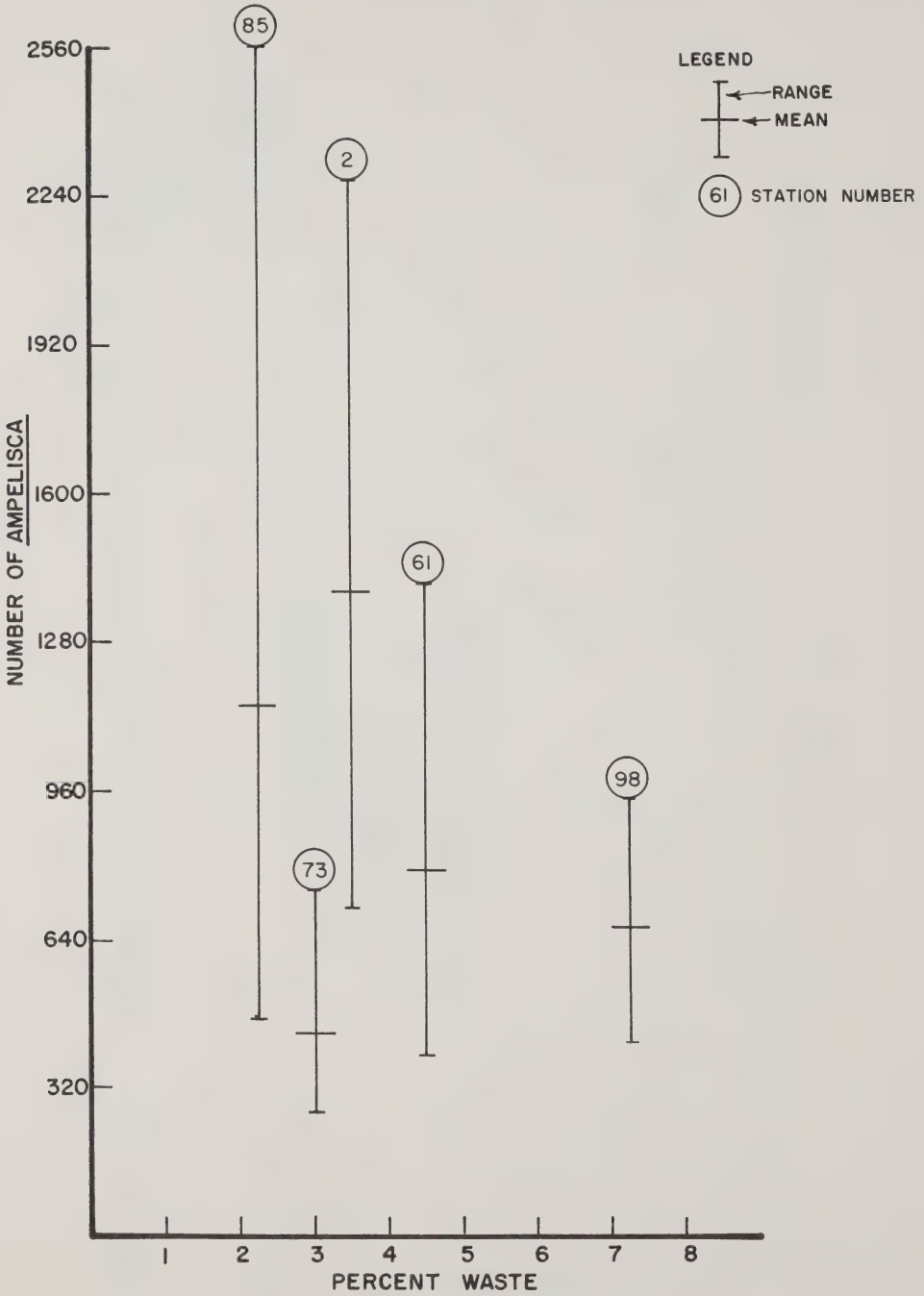


FIGURE 17
RELATIONSHIP BETWEEN WASTE CONCENTRATION AND NUMBERS OF AMPELISCA SP.
AT SAN LEANDRO COVE AREA, APRIL 1971



of animals which are similar to those found in October. However, both relationships, but particularly the waste concentration-number relationship, were less distinct, due to greater within station variances and more irregularities among stations.

As was the case in October, the amphipod Ampelisca was the dominant animal and the invertebrate population abundance largely reflects its abundance. Figure 17 indicates the relationship of Ampelisca numbers to waste concentrations, and Figure 18 shows what the diversity indices are when Ampelisca is excluded from the computations. In this case, elimination of Ampelisca obliterates the trend in diversity.

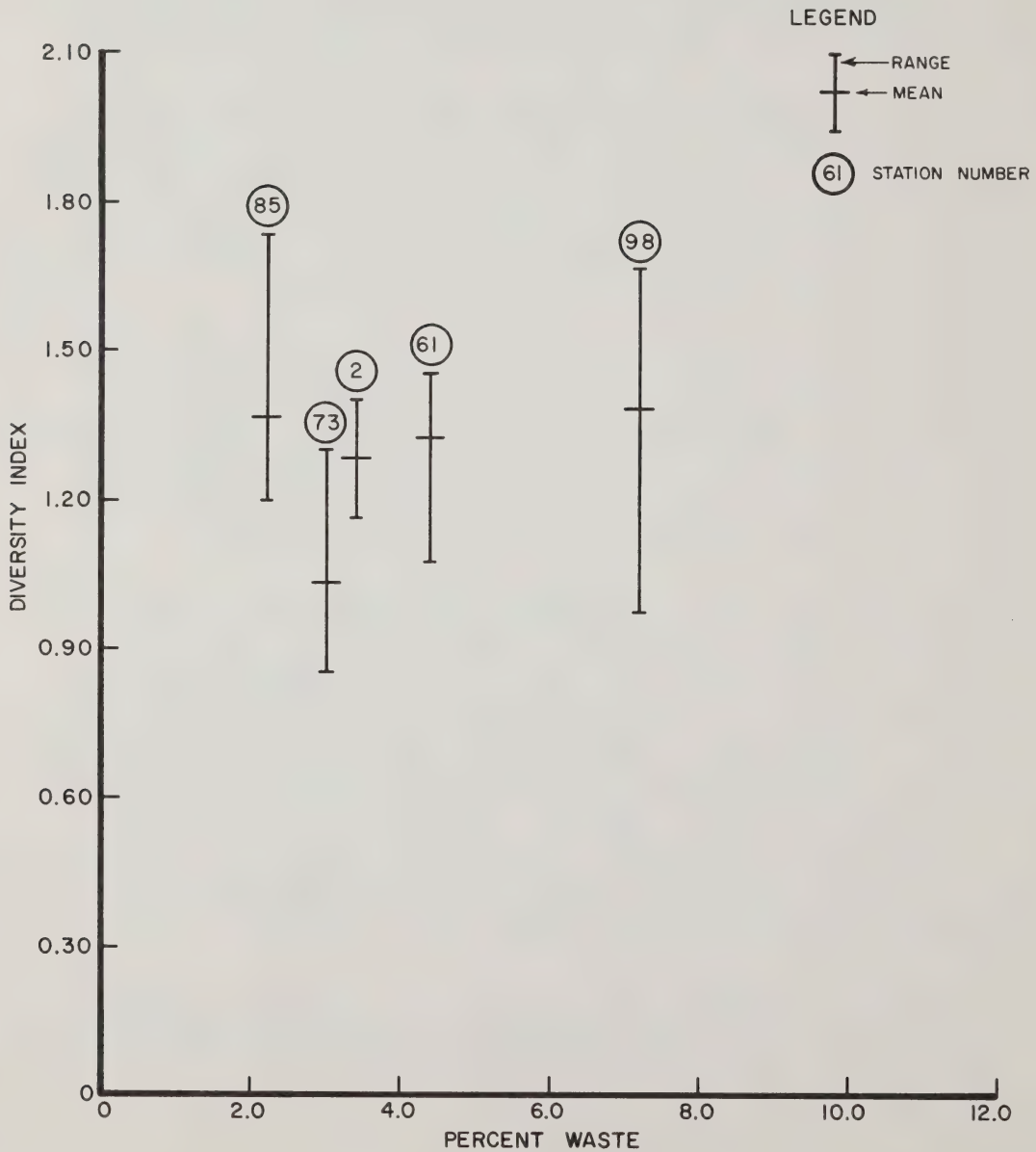
Dissolved oxygen concentrations were below 5 mg/l at all but one of the stations. This was apparently due to a failure in the treatment plant. On the day prior to the benthic sampling the No. 2 clarifier and the No. 1 digestor went out of service. This raised the discharged BOD from 4,100 pounds of 12,800 pounds per day. A search of plant records indicates that this was an isolated instance. The similarity of the April and October results suggests that it did not affect invertebrate populations in an obvious manner.

As was mentioned above, the benthic sampling in April was done in conjunction with studies of chlorination as a possible source of toxicity. The application of chlorine to the waste water was suspended for 30 days prior to benthic sampling. The generally similar relationships between waste concentration and both numbers and diversity in October and April indicate that either chlorination did not affect the benthos or the 30-day cessation of chlorination did not provide sufficient time for the populations to change.

Two additional special studies were carried out in the San Leandro cove area. The first was an assessment of the variability of the benthic community within a particular zone of waste concentration. It is well known that many species of benthic invertebrates exhibit patchiness in their distribution. It was reasoned that if all of the three or four samples were collected from a single point within a waste concentration zone, samples might not reflect an existing patchy distribution of the animals and thus would produce an underestimate of variance. For this reason, duplicate stations were established at 2.2% and 7.2% waste. This was done simply by moving 10 yards from the original sampling point and collecting a second set of 3 samples within the same waste concentration zone. These additional samples were sorted and counted as before.

In both cases there was no significant difference between the species diversity indices for the replicate stations. The values were: Station 85-a mean 1.14, range 1.06 to 1.22;

FIGURE 18
RELATIONSHIP BETWEEN WASTE CONCENTRATION AND DIVERSITY
WITH AMPELISCA EXCLUDED FROM CALCULATION
OF D.I. AT SAN LEANDRO COVE AREA, APRIL 1971



Station 85-b mean 1.07, range 0.97 to 1.13; Station 98-a mean 1.70, range 1.48 to 2.114; Station 98-b mean 1.34, range 1.24 to 1.44. It is reasonable to assume that the diversity indices determined for a point in the San Leandro waste concentration zone would be representative for the entire zone.

Numbers of organisms were similar at Station 98, the means being 1,474 and 1,296 while respective ranges were 793-1,997 and 874-1,871. Numbers at Station 85 were dissimilar because of one extreme sample at each substation. Means were 1,297 and 2,209, and respective ranges were 667-1,887 and 1,407-3,559.

A second special study involved the use of artificial substrates in the cove area at San Leandro. Two units were put out at each of four stations. These stations were 73-3.0% waste, 61-4.5% waste, 98-7.25% waste and a station located inshore of Station 98, where the waste concentration was at least 20% (see Figure 8 for the station locations). Appendix A-5 contains the data collected from the artificial substrates. At Station 73 only one of the two units was recovered. The most abundant animal found in or on the substrates was the amphipod Corophium. The numbers of this animal were in indirect proportion to the waste concentration. There were 1,844 in 3% waste, an average of 1,132 in 4.5% waste, an average of 151 in 7.25% waste and 8 in the most concentrated area. Figure 19 is a plot of the diversity indicies for the artificial substrate samples. As can be seen from this data, the diversity in general was low but increased greatly at the highest waste concentration. This increase in diversity is due to the lack of dominance by Corophium that was observed at the rest of the stations. Figure 20 is a plot of the numbers of animals recovered from the substrates. As with the grab sample data, the trend is toward a significant reduction in the fauna as the waste content of the receiving water increases.

Summary. There are a few general observations which can be made from the studies conducted in October 1970 and April 1971 in the San Leandro area. It is evident from our results that there is a direct relationship between waste concentration and diversity index. Figures 11, 15, and 19 show that as the waste content of the receiving waters increased, higher diversity indices were obtained. Secondly, it was noted that the numbers of animals recovered from a single grab sample or artificial substrate sample could be expected to decrease as the waste content of the receiving water increased (Figures 12, 16, and 20).

It is probable that a toxic component of the waste caused these relationships, and the April results indicate that either chlorination was not responsible for the principal toxic component or the effects of chlorination persist for longer than a month.

FIGURE 19
DIVERSITY INDICES COLLECTED FROM ARTIFICIAL SUBSTRATES FOR STATIONS AT SAN LEANDRO COVE AREA APRIL, 1971

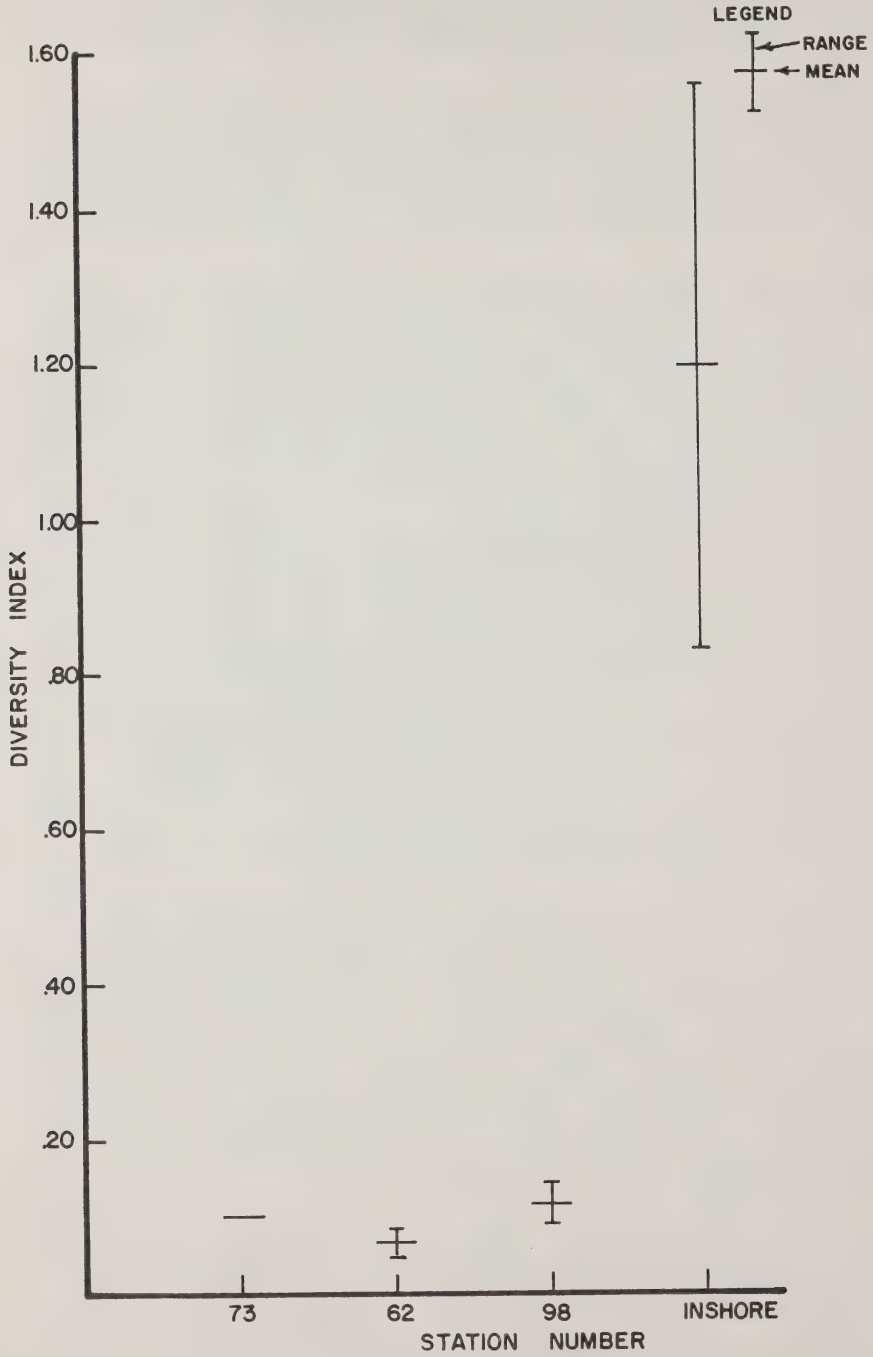
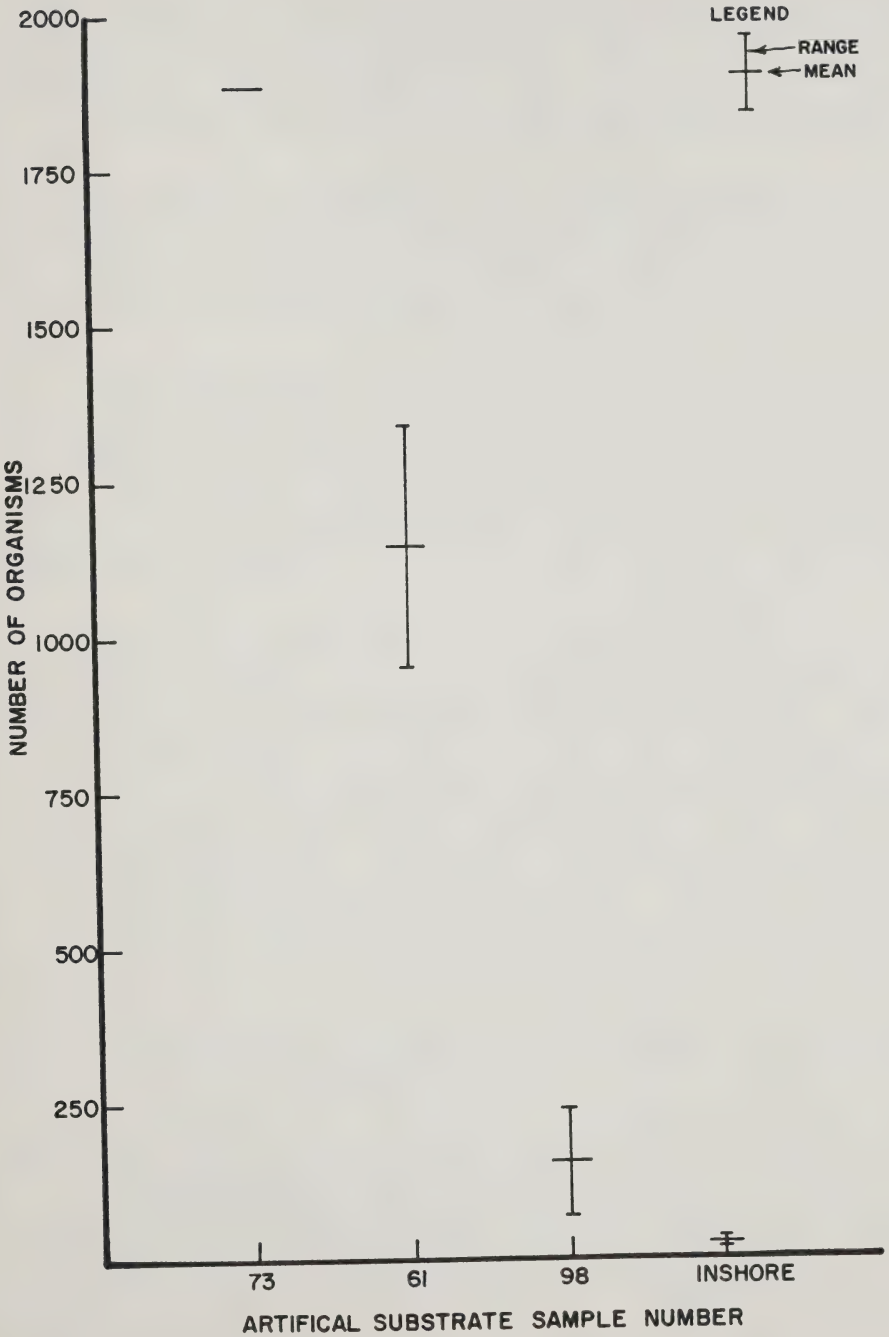


FIGURE 20
NUMBER OF ORGANISMS COLLECTED FROM ARTIFICIAL SUBSTRATES FOR STATIONS AT SAN LEANDRO COVE AREA APRIL, 1971



LOWER SAN JOAQUIN RIVER

September 1970

An 11-mile reach of the lower San Joaquin River from the mouth of False River to New York Slough was chosen as a study area. In the lower half of this reach, approximately from the Antioch Bridge to New York Slough, there are a number of municipal and industrial waste discharges. It was our objective to assess the impact of these waste sources on the benthic community in this area.

Table 2 contains descriptions of the sampling station locations. The stations are approximately 3/4 of a mile apart and are numbered consecutively. Although Table 2 indicates 14 stations, only 9 were sampled in September 1970 and 12 were sampled during a second investigation in March 1971. The September study will be presented first.

Figure 21 is a plot of the estimated percent of relative toxicity loads found at points in the study area along the lower San Joaquin River. The curves in this figure were generated by utilizing data from bioassays of waste waters discharged in the study area (Volume 3) and a mathematical model of dispersion in this portion of the estuary (Volume 5). Details of the calculations are presented in Volume 5 of this report. Mean flows for the month prior to sampling were used in model calculations.

Figure 21 indicates a steady rise in RT concentration from the mouth of False River to a point just downstream of West Island, followed by a decrease to New York Slough. There are some sources of relative toxicity which were not included as input to the model, so Figure 21 should be interpreted with this in mind. The major deviation from reality is that toxicity from wastes discharged downstream from Pittsburg was not included in the estimates. Previous calculations (letter from R. H. Lewis to James Welsh, June 1970) indicate that toxicity downstream from the peaks in Figure 21 is essentially constant. Those calculations also showed that at the point of peak concentration (West Island), sources west of Pittsburg constituted less than 10% of the total toxicity.

Another source of error is that no estimate was included of toxicity from the U. S. Steel Company plant at Pittsburg, because no bioassay information was available.

Another important assumption is that no acute toxicity enters from upstream. This is probably reasonable, because the nearest noteworthy discharge is about 20 miles upstream. Agricultural drainage water is a possible upstream source of toxicity, although the drainage water probably is not acutely toxic, so its contribution to the relative toxicity load is probably indeterminate.

TABLE 2

ANTIOCH BENTHIC SAMPLE STATION LOCATIONS

Station #1	Approximately 1/2 mile above mouth of False River on north side of San Joaquin River; 20 ft. deep.
Station #2	100 yds. downstream from mouth of False River on north side of San Joaquin River; 20 ft. deep.
Station #3	Directly opposite Standard Oil sign at Eddo's Harbor on north side of river; 20 ft. deep.
Station #4	Directly opposite Blind Point on north side of river; 20 ft. deep.
Station #5	Directly out from siphon pump on north side of river, approximately 1/2 mile upstream from Antioch Bridge; 20 ft. deep.
Station #6	200 yds. downstream from Antioch Bridge on north side of river near "Gas Line Crossing" sign; 20 ft. deep.
Station #7	Near north shore of river at the downstream tip of West Island; 20 ft. deep.
Station #8	Near south shore of Kimball Island on north side of channel off of two small houses on Island; 20 ft. deep.
Station #9	In Broad Slough near east shore of Winter Island 1/2 mile north of Light FL 4 sec 21 ft. "2"; 20 ft. deep.
Station #10	Off tip of Winter Island at FL G 4 sec "2"; 20 ft. deep.
Station #11	At Light FL G 4 sec 18 ft. "11" near upstream end of New York Slough; 20 ft. deep.
Station #12	In New York Slough at Light FL G 4 sec 20 ft. "7"; 20 ft. deep.
Station #13	In New York Slough at Light FL G 4 sec 18 ft. "5"; 20 ft. deep.
Station #14	In New York Slough at Light FL G 4 sec "3"; 20 ft. deep.

FIGURE 21

ESTIMATED RELATIVE TOXICITY CONCENTRATIONS RESULTING FROM WASTE DISCHARGES IN THE PITTSBURG-ANTIOCH AREA

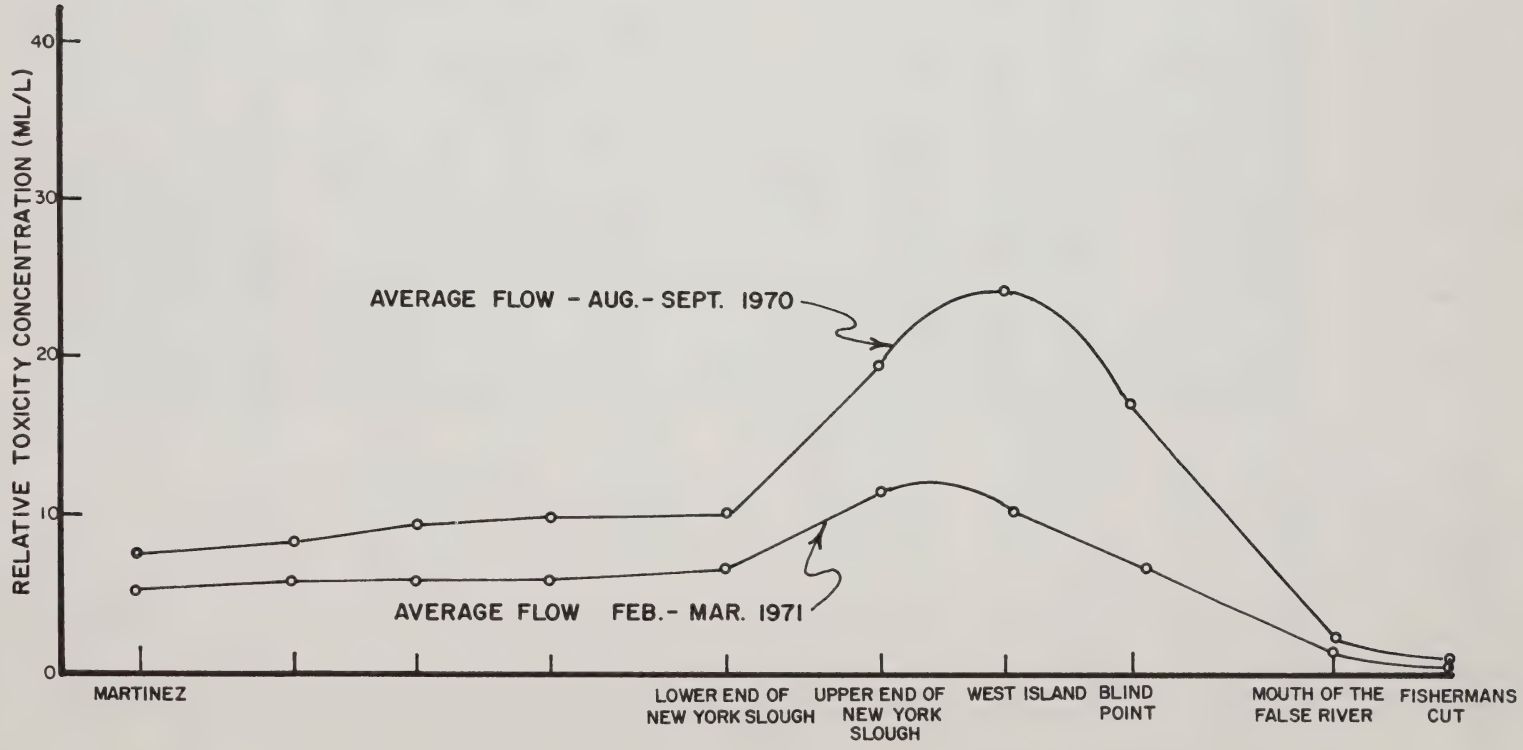


FIGURE 22
BENTHIC INVERTEBRATE: DIVERSITY FOR STATIONS IN THE LOWER SAN JOAQUIN RIVER, SEPTEMBER 1970

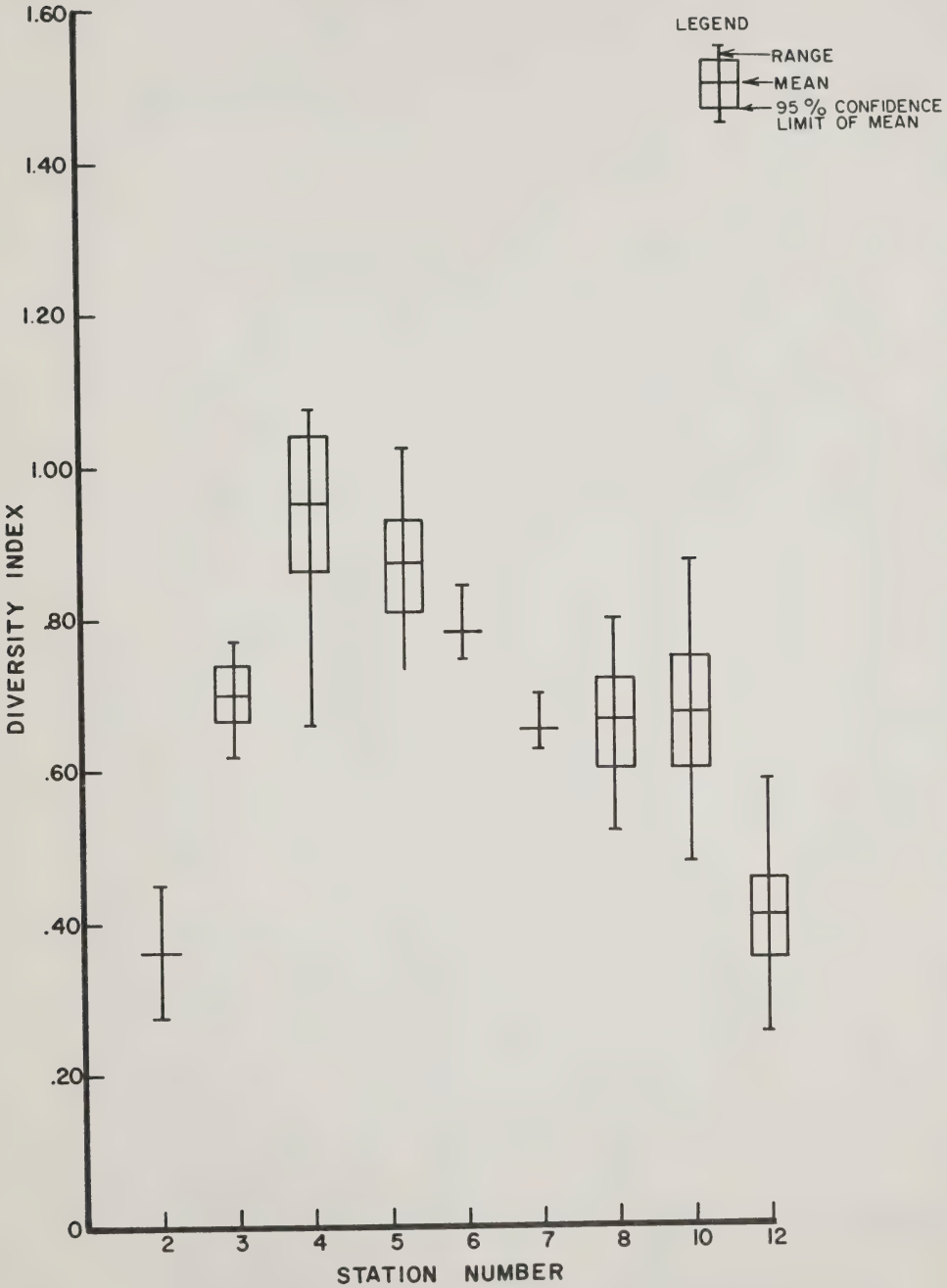


FIGURE 23
NUMBER OF BENTHIC INVERTEBRATES FOR STATIONS IN THE LOWER SAN JOAQUIN RIVER SEPTEMBER, 1970

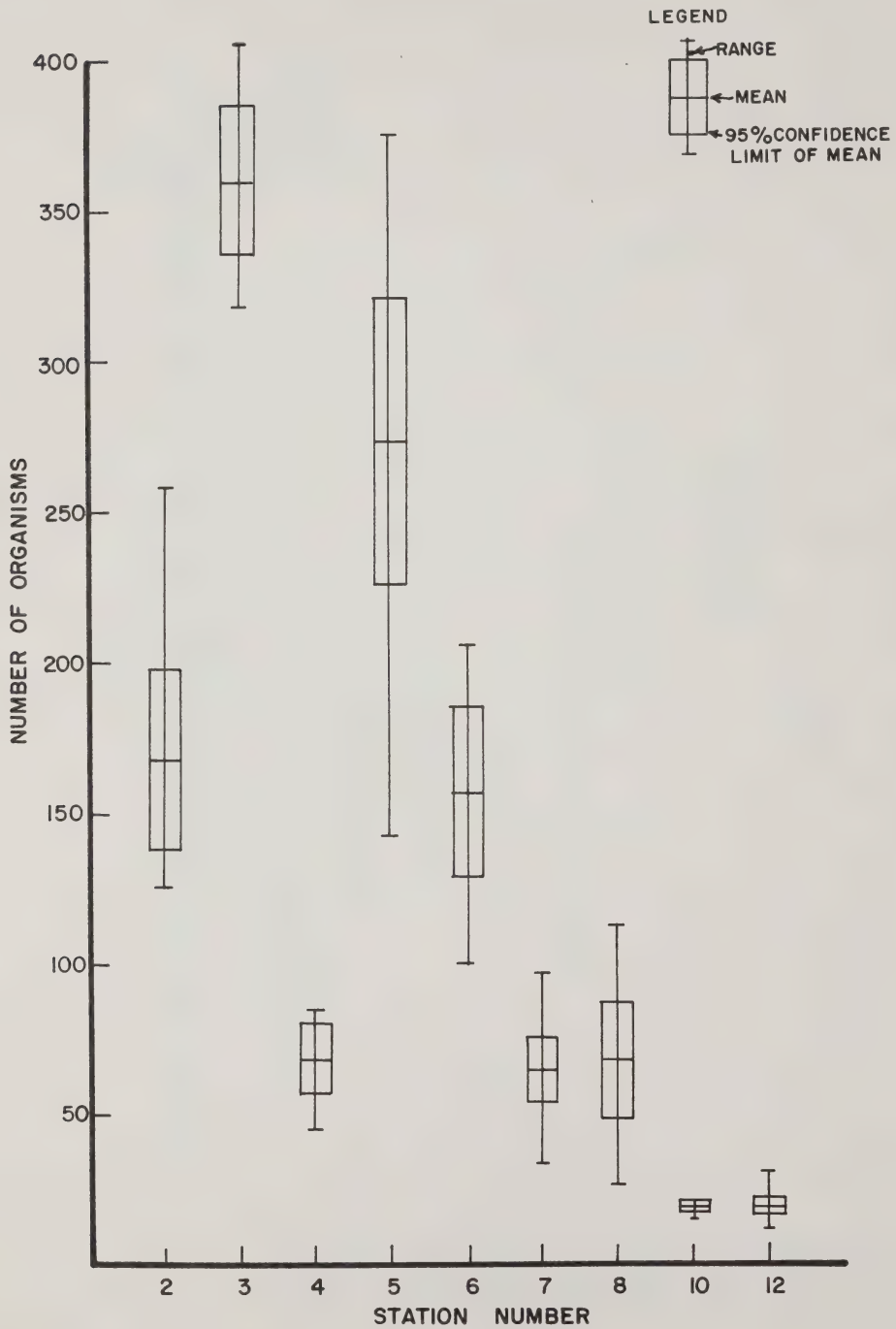


FIGURE 24
NUMBER OF COROPHIUM AND CORBICULA AT STATIONS
IN THE LOWER SAN JOAQUIN RIVER, SEPTEMBER, 1971

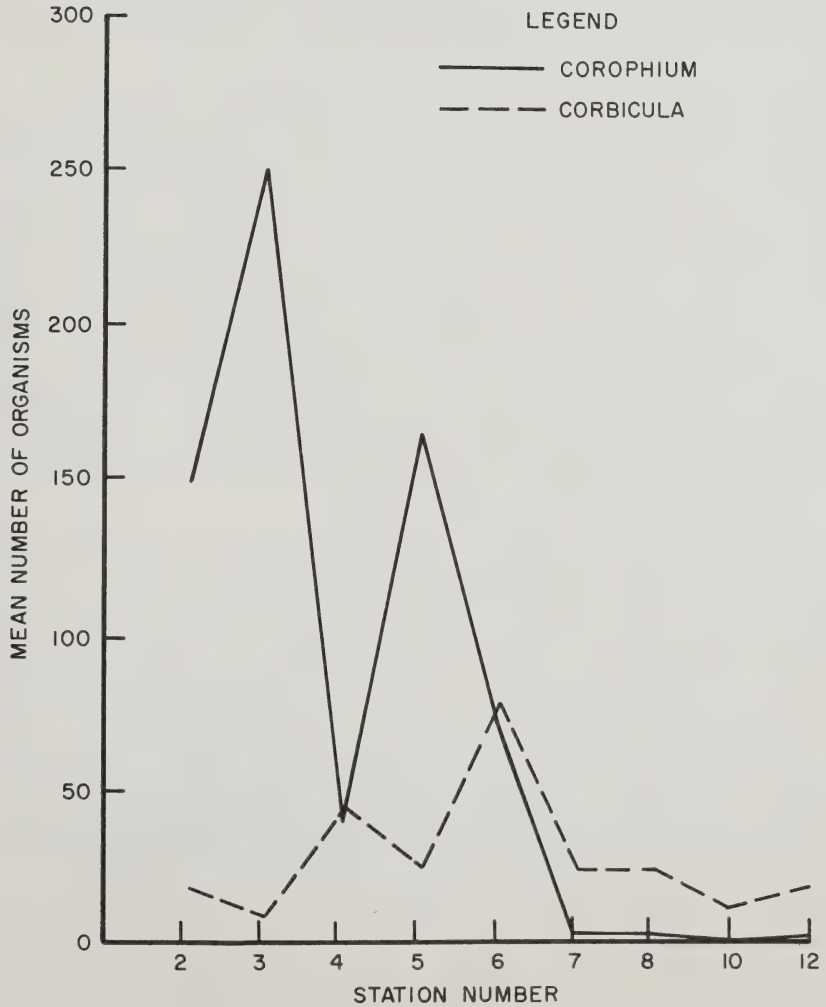


Figure 22 shows the diversity indices determined from the data which are included in Appendix A-6. The mean diversity index was low, 0.372, at the mouth of False River (Station 2) and increased to 0.934 at Station 4, which is directly opposite Blind Point. Diversity then decreased downstream, with the mean diversity index at New York Slough being only 0.408.

Figure 23 is a graph of the numbers of animals recovered at the benthic sampling stations. A trend similar to that for diversity exists. There was an unusual drop in numbers at Station 4, and no reason is apparent for this.

The benthos in the study area is composed largely of three species: The amphipod, Corophium stimpsoni, the clam, Corbicula manilensis, and a tubificid oligochaete. The numbers of Corophium and Corbicula are plotted in Figure 24. Upstream from Station 6, total numbers essentially reflect numbers of Corophium, and the trend in total numbers largely reflects the distribution of Corophium. Corophium numbers dropped substantially at Station 4. No reason for this is apparent.

It was previously noted that the versatility of the diversity index equation makes it possible to use any measurements of abundance for calculation of DI. In the Antioch area this was done by using dry weight of each species, as well as numbers. Figure 25 is a plot of the diversity indices calculated using dry weight. In general, there is a trend which follows that of diversity indices based on numbers of each species (Figure 22), although the trend is less distinct and variances are considerably greater. Station 12 in New York Slough deviates from the trend, but this can be explained by the presence of a proportionately high number of clams which did not weigh enough to dominate the community and lower the diversity index. In general the difficulty of obtaining unbiased weights of animals with shells, such as Corbicula, makes diversity indices based on weight less valid than diversity indices based on species counts.

Interpretation of the results presented above required information about other environmental parameters. There was some degree of variability in substrate composition between the sample stations. Bottom samples from stations 2, 3, 4, 5, and 10 were made up of a high percentage of sand 0.149 mm or finer in diameter, while Stations 6, 7, 8, and 12 had a greater percentage of sands which were retained on a screen with a mesh having 0.297 mm openings (Appendix B-6). The significance of these differences is difficult to evaluate. There seems to be no reflection of these differences in the diversity indices or numbers of animals per station. For our purpose, it will have to be assumed that the differences were not of a magnitude which influenced populations.

FIGURE 25

BENTHIC INVERTEBRATES DIVERSITY INDICES BASED ON DRY WEIGHT PER SPECIES IN THE LOWER SAN JOAQUIN RIVER SEPTEMBER, 1970.

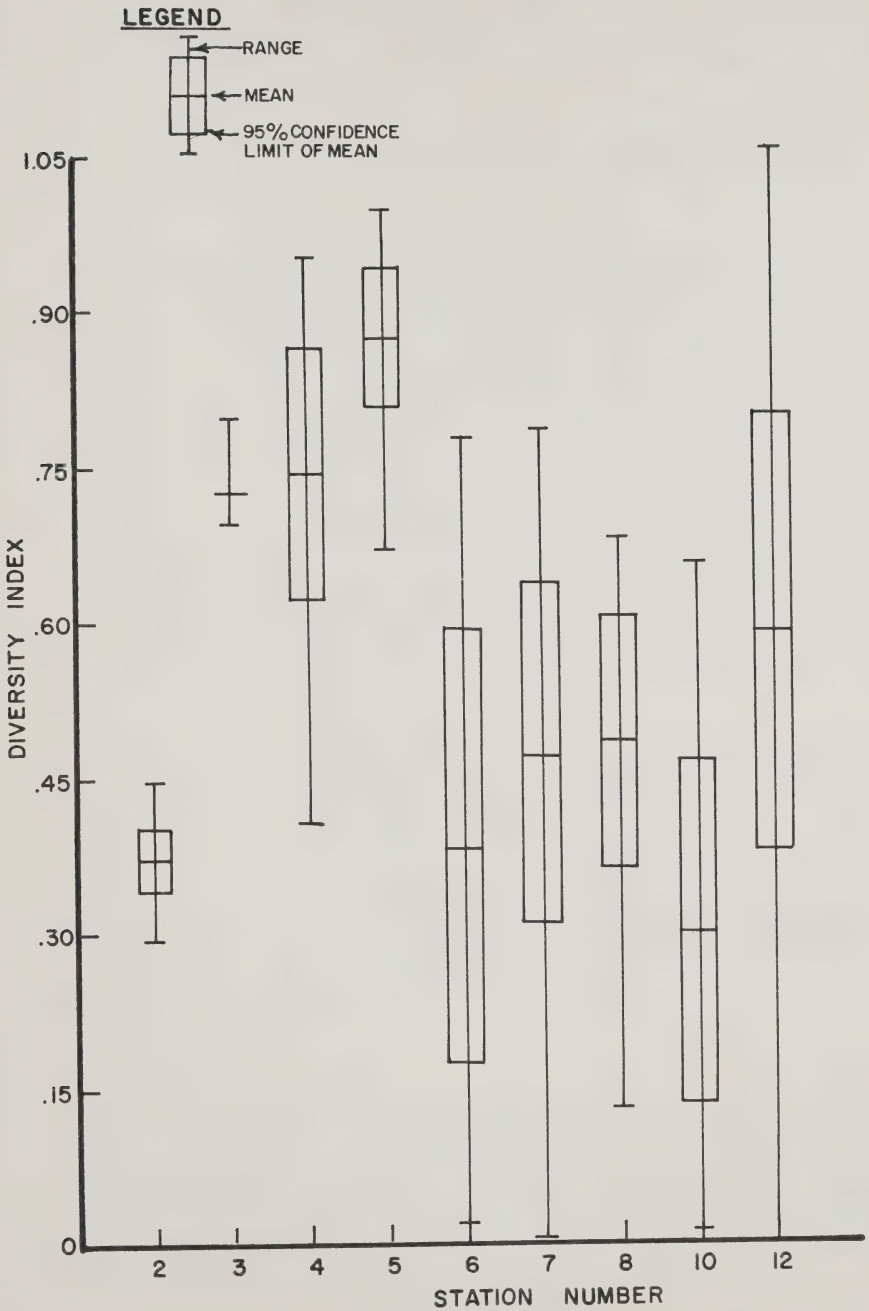
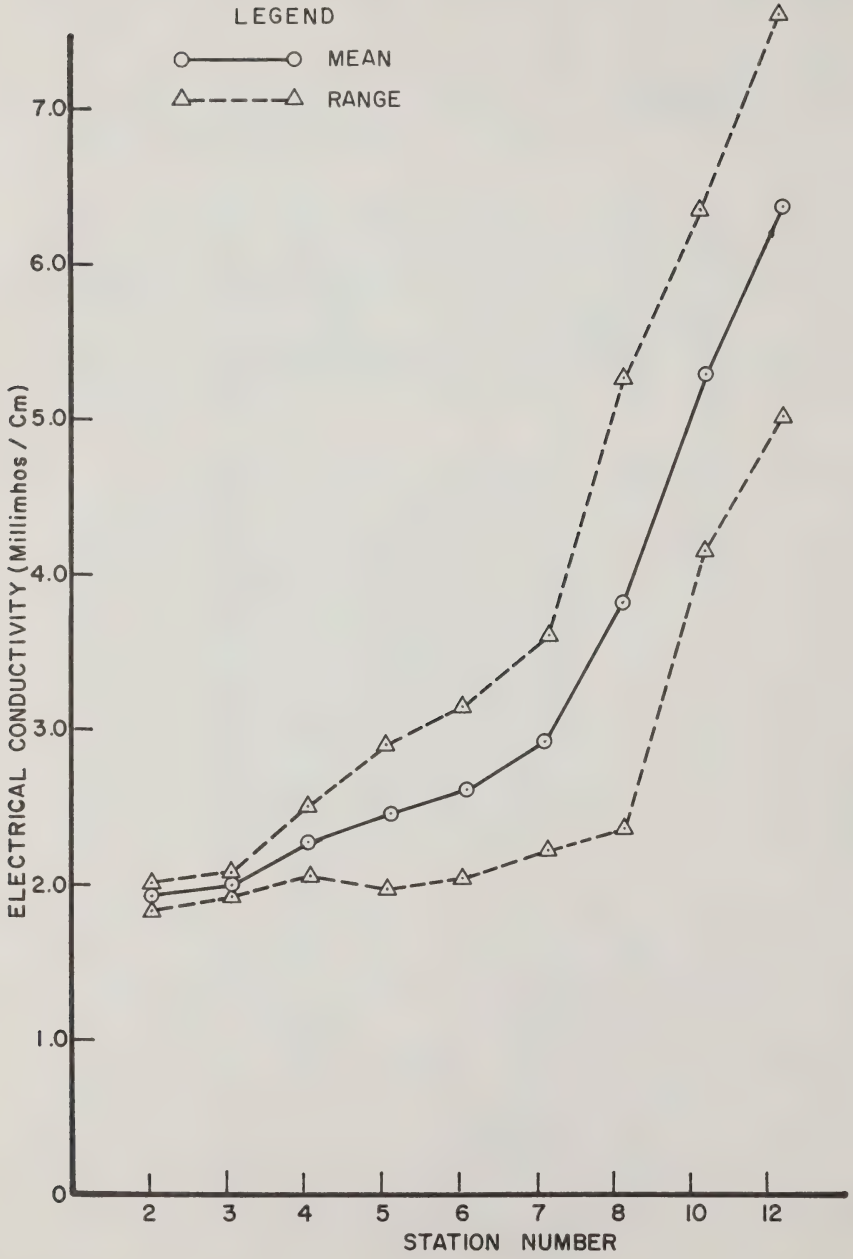


FIGURE 26
ELECTRICAL CONDUCTIVITY FOR STATIONS IN THE LOWER SAN JOAQUIN RIVER
SEPTEMBER, 1970



The chemical analysis of the substrates is in Appendix C-6. These data do not indicate abnormally high amounts of any of the elements measured, nor are population characteristics correlated with variations in chemical concentrations. A possible exception to this is the grease and oil found at Station 7, where 4,200 mg/kg was found. This concentration conceivably could have caused the depression in the number of animals at Station 7.

DO, pH, and temperature measurements were within a range that would generally be considered tolerable for benthic invertebrates.

A few days prior to the benthic sampling, an investigation into the salinity changes in the study area was conducted to gain background information which might help to interpret results. Samples were collected and electrical conductance measured at each of the stations. The approximate salinity in mg/l of total dissolved solids can be estimated by multiplying electrical conductance by 0.64. Measurements were made during high slack and low slack tides in order to obtain the extremes. Figure 26 is a plot of the mean of the E.C.'s found at each of the stations. From this it can be seen that there is a gradual increase between Station 2 and Station 7 followed by a sharp increase in E.C. between Stations 7 and 12. The rise in electrical conductivity between Stations 7 and 12 is followed closely by a drop in the number of animals per sample. This possible relationship is most easily seen in Figure 24, where the numbers of Corophium are seen to drop sharply at Station 7 and to remain low downstream from that station.

Figure 21 shows that a peak in relative toxicity occurs at West Island, which is where Station 7 is located, and we can see from Figure 26 that a sharp change in the mean electrical conductivity occurs in the same area.

The trend of decreasing diversity and numbers with distance downstream parallels both salinity and toxicity, although these trends do not flatten downstream from Station 7 where toxicity probably becomes relatively constant. No reason is apparent for the depression of diversity and numbers at the uppermost stations.

March 1971

A study of benthic communities in the lower San Joaquin River near Antioch was conducted for a second time in March of 1971. The second sampling was carried out in the spring, when lower salinities and a reduced salinity gradient were expected. The station locations are included in Table 2. Twelve stations were sampled from 1/2 mile above the mouth of False River to the downstream end of New York Slough.

FIGURE 27
BENTHIC INVERTEBRATE DIVERSITY FOR STATIONS IN THE LOWER SAN JOAQUIN RIVER MARCH, 1971

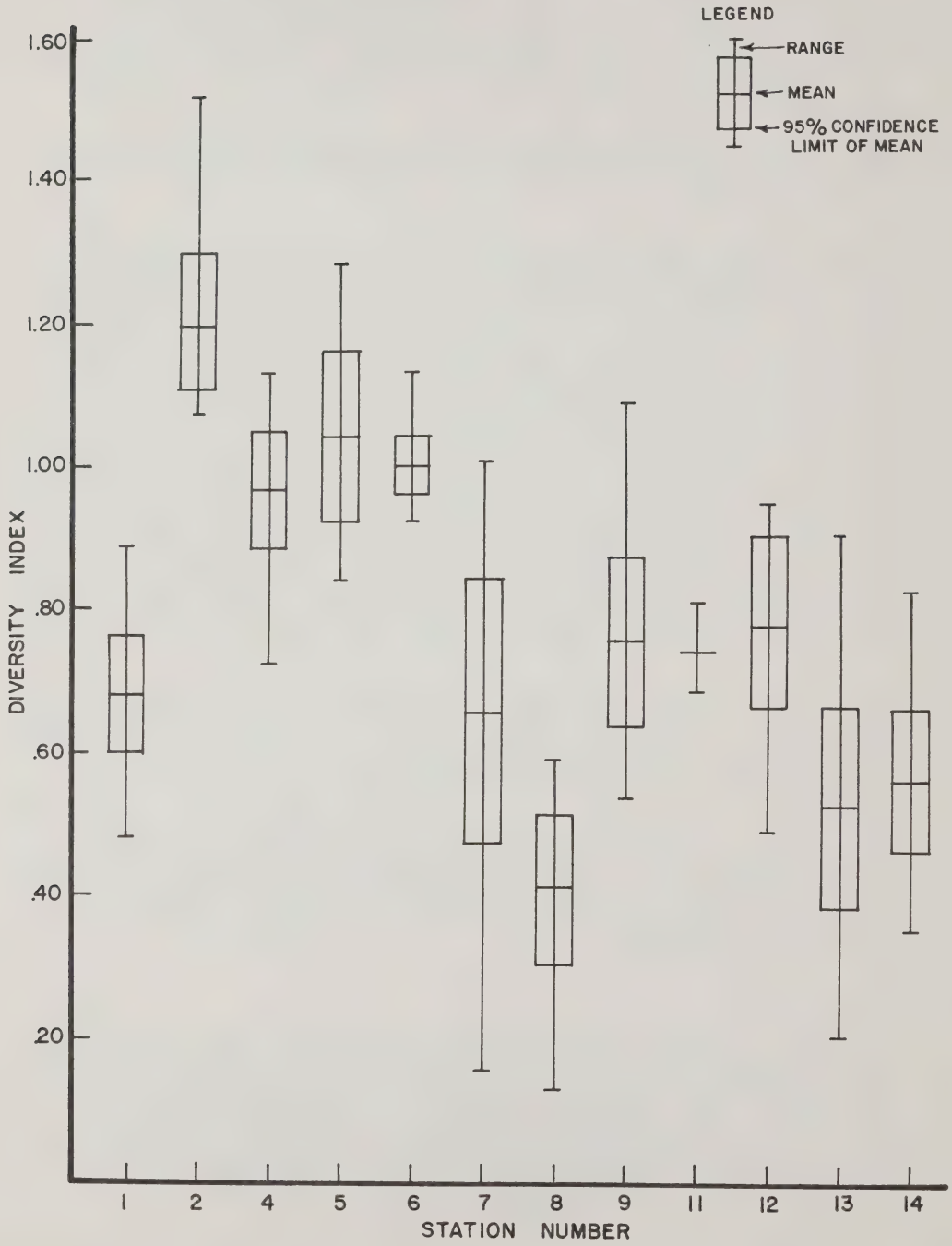


Figure 21 contains a plot of the estimated relative toxicity in the area. As before this was calculated using the dispersion model of the area and bioassay results (see Volumes 3 and 5). The peak in the relative toxicity curve occurs slightly farther downstream than it did in September. This situation, along with the lower concentrations, was to be expected since flows were higher than in September.

Appendix A-7 contains the data obtained by the benthic sampling. The benthic community was composed again of three main species, Corophium stimpsoni, Corbicula manilensis, and the tubificid oligochaete. There were some additional annelids which were not found in the September samples. The species diversity indices were generally higher in March than in September. A comparison of Figure 27 with Figure 22 shows that diversity indices in March averaged approximately 0.20 higher at the stations which were sampled also in September. This situation is due to the additional species recovered from the March samples.

Diversity generally decreased as one moves downstream from False River, although the decrease was not as pronounced as it was in September. It is interesting to note that low diversity was found again at the station farthest upstream. As was the case in September, there is no ready explanation for this. Between Stations 7 and 8, there is a drop in mean diversity index of about 0.25; this is approximately the point where the peak in relative toxicity occurs (Figure 21).

Figure 28 is a graph of the number of animals recovered from the samples. There is a general trend indicating reduced numbers downstream. The numbers of animals at each station are similar to the September data. The deviation at Station 12 results from two of the four samples containing unusually high numbers of Corophium and tubificids. This is an example of the patchiness which many benthic invertebrates exhibit. The numbers of Corophium and Corbicula per sample, although variable, tend to decrease downstream (Figure 29).

Dry weights for each species from every sample were determined and used to calculate diversity indices (Figure 30). There is a slight trend in this data which follows that of diversity indices based on counts (Figure 27). The greater variances in diversities indices based on dry weights is probably due largely to inaccuracies involved in weighing clams.

The substrate composition analysis is presented in Appendix B-7. Bottom samples from stations 1 through 6 were composed mainly of fine material. About 50% of the material was retained on a screen with openings of 0.053 mm. Substrates at Stations 7 through 13 were somewhat coarser, having the major portion of the material retained on a screen with 0.297 mm openings. Station 14 is intermediate. In general the observed trends of diversity and numbers do not appear to be related to these differences.

FIGURE 28
NUMBER OF BENTHIC INVERTEBRATES FOR STATIONS IN THE LOWER SAN JOAQUIN RIVER MARCH, 1971

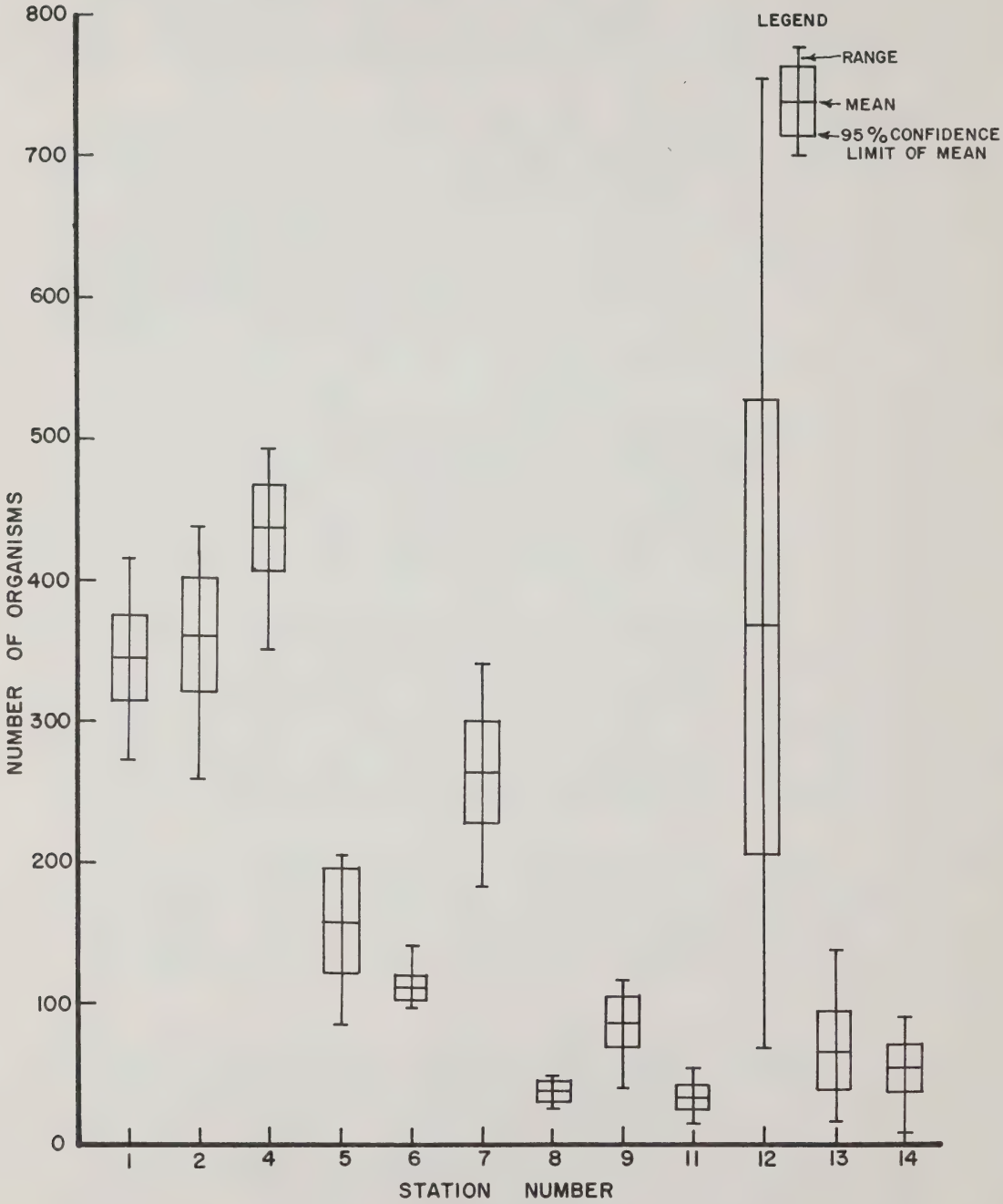


FIGURE 29

NUMBER OF COROPHIUM AND CORBICULA AT STATIONS IN THE LOWER SAN JOAQUIN RIVER, MARCH, 1971

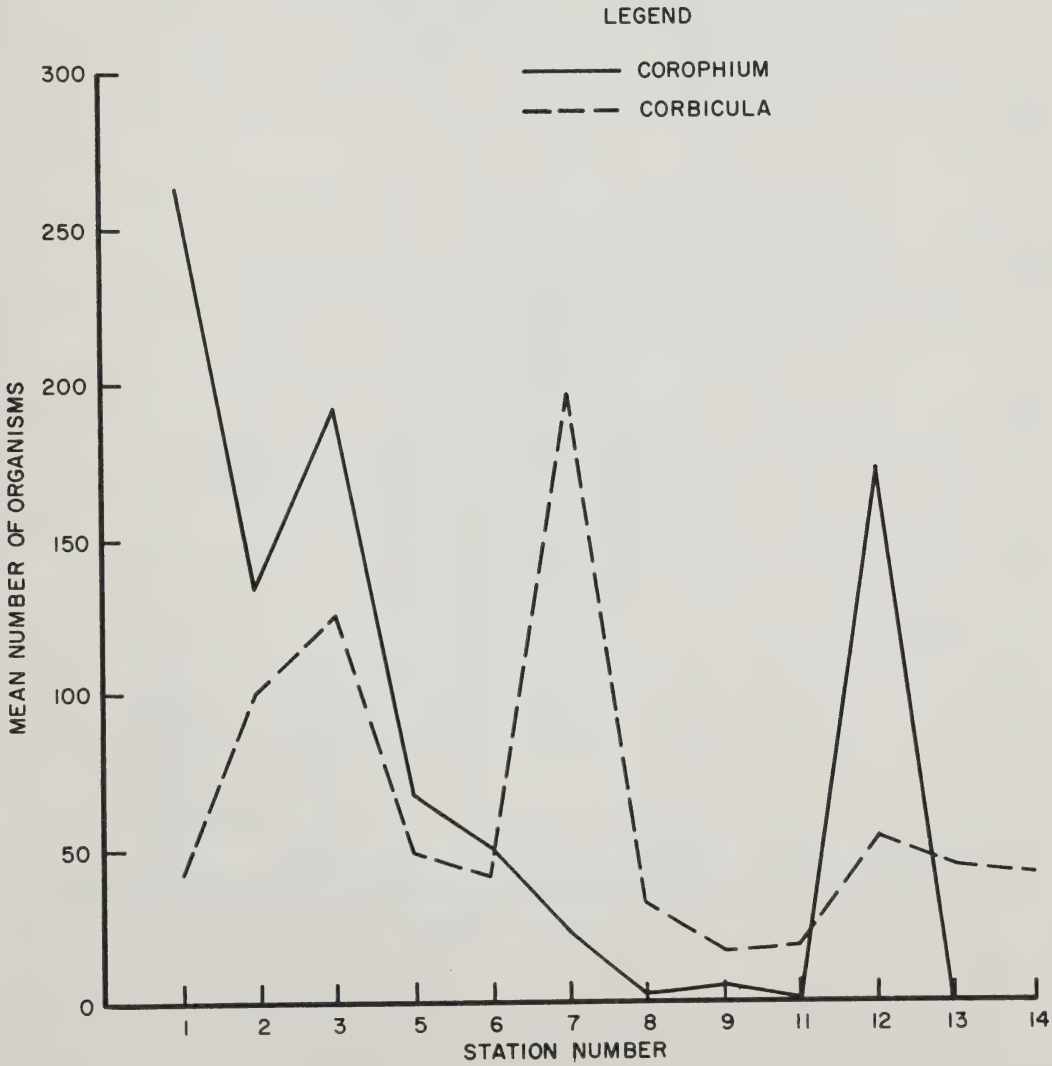
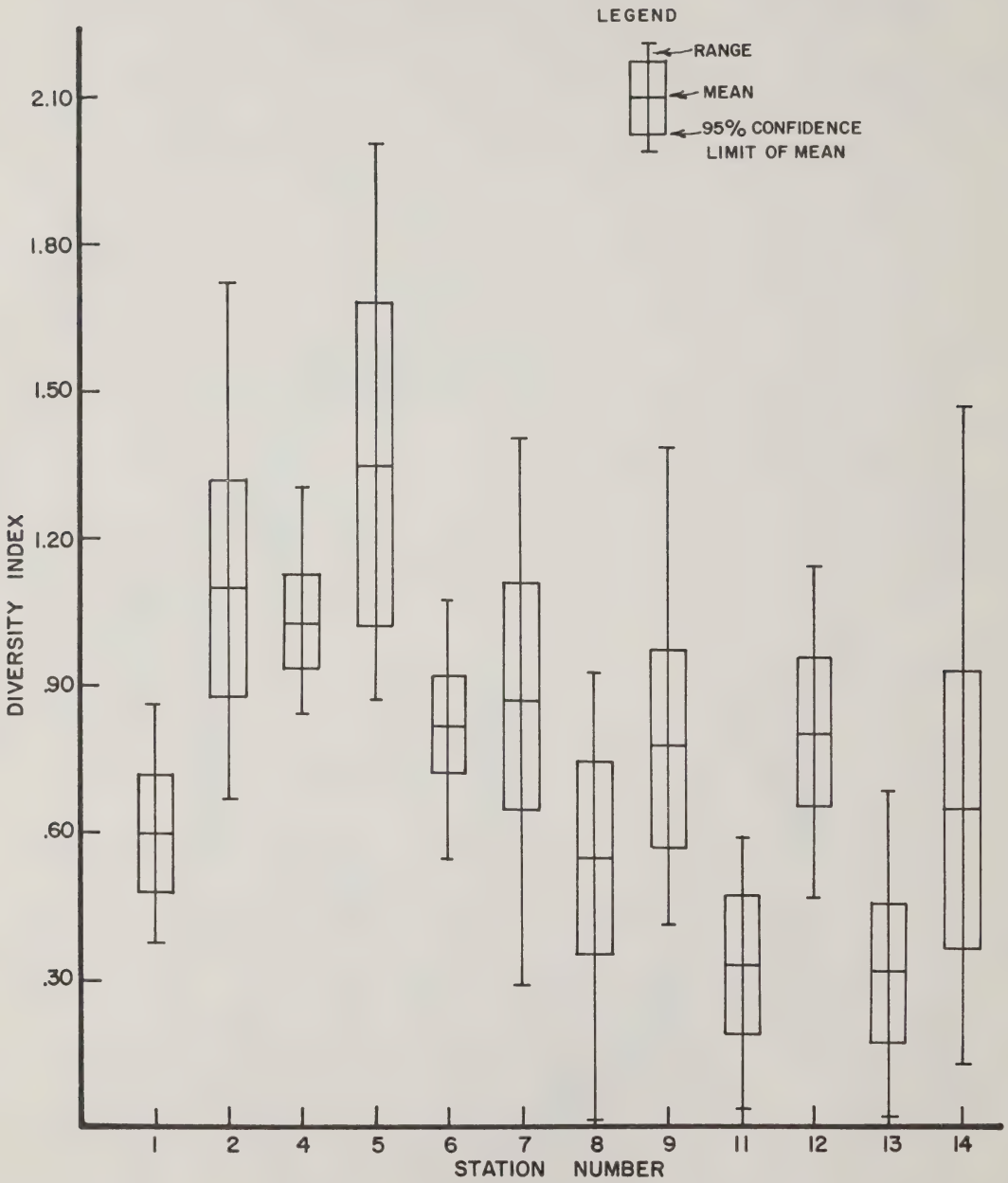


FIGURE 30
BENTHIC INVERTEBRATES DIVERSITY INDICES BASED ON DRY WEIGHT PER SPECIES
IN THE LOWER SAN JOAQUIN RIVER MARCH, 1971



Appendix C-7 contains the chemical analysis data for the sediments. Concentrations of a few of the chemicals changed substantially between September and March. The heavy metals generally increased 2 to 3-fold and iron increased from approximately 3 to 7 mg/kg to more than 30 mg/kg at Stations 6 through 12. We have no explanation for these increases. In general, the amounts of metals still probably do not exceed tolerance limits for most invertebrates and thus would not affect the benthos to any large degree.

There was no supplemental study on salinity conducted in March, so mean monthly values from continuous electrical conductivity monitors at Jersey Point, Antioch, and Pittsburg were used. Respective means for March were 140, 157 and 236 mg/l TDS (U. S. Bureau of Reclamation, unpublished data). These means indicate that the salinity from Station 7 upstream differed by less than 10% from the values measured in September 1970. Downstream from Station 7 the gradient in March was less steep with the salinity estimated by interpolation at Station 12 being about 50% of the September measurement.

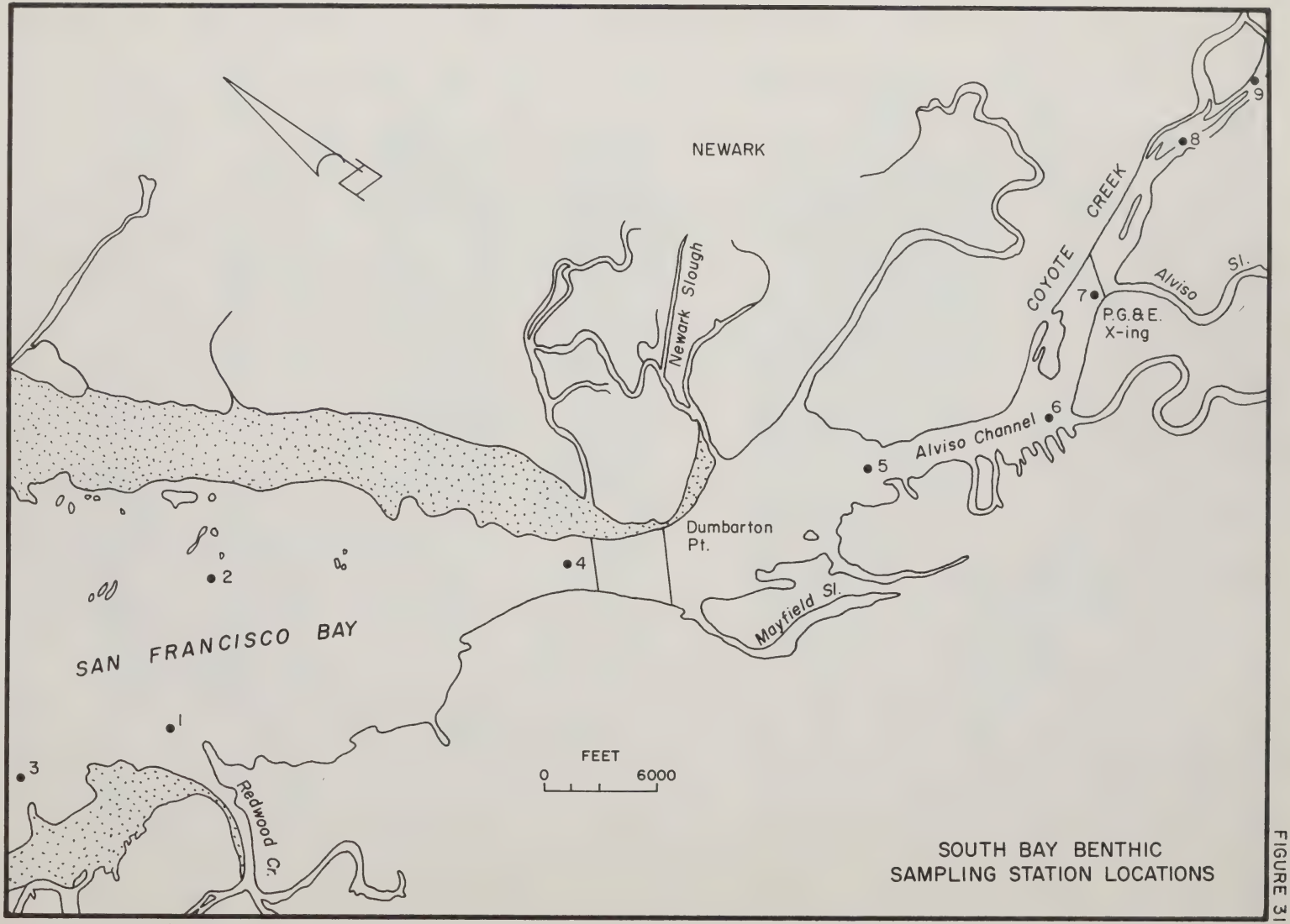
SOUTH AND LOWER BAYS

In mid-April 1971, benthic samples were collected from 9 stations in South San Francisco Bay and 4 stations in Lower San Francisco Bay. The points which were sampled correspond to and are labeled the same as those in the U. C. Bay Study. The locations of these stations are plotted on Figures 31 and 32.

The original intent of this part of the study was to make a tentative evaluation of whether the diversity-waste discharge relationship observed during the U. C. Bay Study still exists. This was subsequently judged to be impossible, chiefly because estimates of diversity depend upon the level of identification. Since that varied in the two studies, no meaningful comparison can be made.

The results of the current study show that the benthic fauna is still sparse in parts of this region. It is presented here, so that it is available for any future evaluations. Its chief values are the measure of total benthic invertebrate abundance and the abundance of certain species and genera which could be identified.

Appendices A-8 and A-9 contain the results of the faunal counts. Figure 33, a plot of the numbers of organisms taken at the various stations, exhibits a general lack of trend.



SOUTH BAY BENTHIC SAMPLING STATION LOCATIONS

FIGURE 31

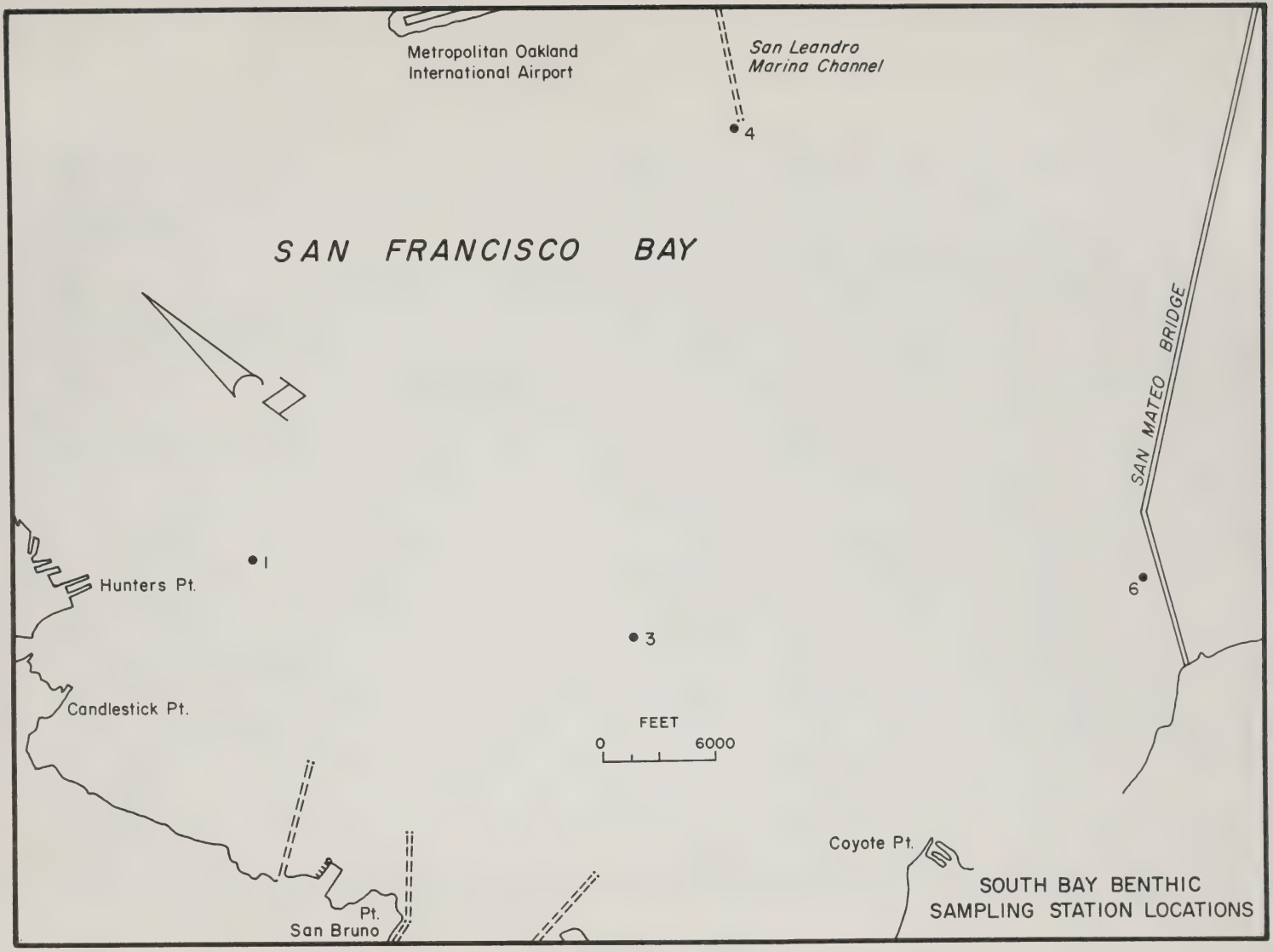
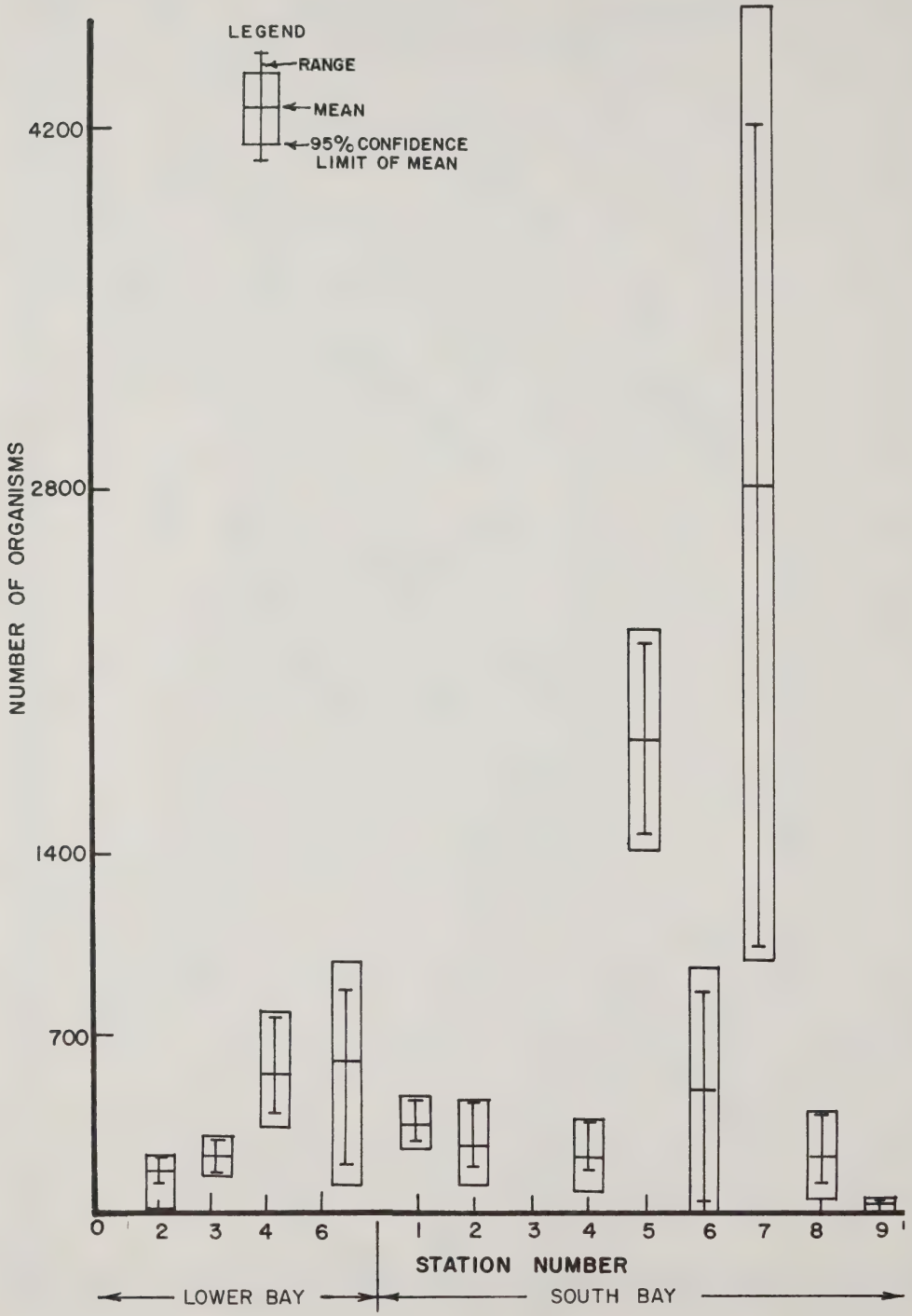

Metropolitan Oakland
International Airport
San Leandro
Marina Channel
4
SAN FRANCISCO BAY
SAN MATEO BRIDGE
1
Hunters Pt.
3
6
Candlestick Pt.
FEET
0
6000
Coyote Pt.
Pt.
San Bruno
SOUTH BAY BENTHIC
SAMPLING STATION LOCATIONS

FIGURE 32

FIGURE 33
NUMBER OF ORGANISMS AT STATIONS IN LOWER AND SOUTH SAN FRANCISCO BAY
FOR SAMPLES COLLECTED IN APRIL, 1971



The variability of this data and the lack of distinguishable trends is not unexpected since no attempt was made to keep environmental variables constant. Dissolved oxygen, measured at the time of sampling, ranged from 9.0 down to 5.8 mg/l. The latter dissolved oxygen figure is for South Bay Station 9, which when sampled had water only 3 feet deep during a high tide. The dissolved oxygen probably was even less at a low tide. Electrical conductivity, temperature, and pH did not vary greatly. The water depth of the stations ranged from more than 40 feet at stations in mid-channel to only 3 feet deep at high tide at Station 9.

The substrate composition exhibited some degree of variability also. Stations 3 and 4 in South Bay were considerably coarser and had a wider range of particle sizes than the other South Bay stations (Appendix B-8). The Lower Bay Stations 2, 3 and 6 had substrates fairly similar to South Bay Stations 3 and 4, while the substrate at Lower Bay Station 4 was essentially the same as that at the other South Bay stations (Appendices B-8 and B-9).

Three stations were selected for substrate chemical analysis (Appendix C-8). From this limited amount of data it is not possible to identify important differences between the stations examined. The only value with probable biological significance was a grease and oil concentration of 1,600 mg/kg at South Bay Station 9.

IV. DISCUSSION

SAMPLING RELIABILITY

Among the general considerations of this report is an analysis of the precision of the results. Precision is a measure of the variability in a set of results. Variability is typically great for samples of benthic invertebrates, because the animals are unevenly distributed and individual samples cover small areas. In the present study, consideration of time and budget had to go along with a desire for maximum precision. The original study plan called for four samples to be analyzed from each station. In most cases, this proved to be too many in terms of manpower and time available; therefore, three samples were processed at each station.

Precision was quite good in the lower San Joaquin River, particularly in the fall, and at San Leandro in the fall. There confidence limits (95%) of means of diversity indices and numbers of animals were often on the order of ±10% of the mean and seldom exceeded 25%. For other stations and periods precision was poorer, confidence limits often being ±50% or more of the mean. Variability on this order obviously makes interpretations of results tenuous, and it resulted in apparent trends not being significant statistically.

On the other hand, two kinds of evidence contribute to confidence that observed differences are meaningful. One has to do with the question of whether or not within-station variance is even greater than that reported, because the usual sampling procedure resulted in all samples being collected within a few feet of each other.

This matter was examined through the sets of replicate samples collected from the San Leandro area. Here, three samples were collected in April at the regular station location, then a second set was taken 10 yards away. This test was made at two different stations. The results indicated no significant difference in diversity between the replicates, suggesting that samples at a station are reasonably representative of populations over a substantial area of defined habitat type exposed to a given waste concentration.

The second and more important kind of evidence lending confidence is the similarity of trends shown by the two sets of samples taken several months apart both at San Leandro and in the lower San Joaquin River. This similarity demonstrates the validity of the general relationships observed, despite unexplainable departures from trends at individual stations and the fact that differences between means often were not significant statistically.

DIVERSITY INDICES AS INDICATORS OF ENVIRONMENTAL CONDITIONS

The U. C. Bay Study pointed out the potential value of diversity indices as indicators of environmental conditions. It was recognized that an important element in the interpretation of diversity indices is the fact that the numerical value is partially a function of sampling procedures (Storrs, Pearson and Selleck, 1969, VI, p. III-16).

Some animals are motile enough to escape the dredge. The Ponar dredge used in the present study probably behaves very similarly at least in shallow waters in this respect to the Petersen and orange-peel dredges used in the U. C. Bay Study, although evidence for evaluating this supposition is not available.

In both studies 30 mesh screens were used so biases due to loss of the smallest animals should be similar. An attempt was made in the current study to evaluate this bias by using a 60 mesh screen. Little difference was found in the few samples sifted by the two methods, and the difference in sifting time was great. Both of these factors vary with substrate type, though.

Comparability of identification is more difficult to judge. Both studies attempted to identify benthic organisms to approximately the same taxonomic level. Identification of these organisms is difficult because the taxonomy of many groups is incompletely known, and keys covering all organisms in this region are not available. Considering the uncertainties involved though and the fact that U. C. Bay Study samples are apparently no longer available, no valid comparisons will probably ever be possible.

Differences in identification among the various studies of San Francisco Bay have obviously occurred. One example is that the amphipod identified as Ampelisca sp. in this study was apparently identified similarly by Filice, but was identified as Photis californica by the U. C. Bay Study and Painter (1966). Such differences do not affect diversity indices as long as animals are not grouped differently. Considering the uncertainties involved in identification, it seems certain though that some inadvertent differences in groupings must have occurred.

Volume 2 of this report contains a detailed discussion of the mathematical properties of the diversity index used to describe our data. It is appropriate in this discussion, however, to point out some features of the equation. Although the index computed by this equation is not dependent on sample size, it was readily seen that, when samples contained small numbers of animals and species, a relatively slight difference in the counts could result in a notable

change in diversity indices. This was true in the Antioch sampling area, and additional samples were analyzed to reduce error. Conversely as the numbers of animals and species increases, the effect of a small change on the diversity index is decreased.

Dry weights proved to be less suitable than species counts in the lower San Joaquin River for calculating diversity indices because variances were appreciably greater and because of the difficulty of obtaining comparable weights for clams.

In most cases, it was found that the actual numbers of animals, of a particular species or of all species, was as good as or better than the index of diversity as an indicator of environmental conditions, although variability tended to be greater for numbers than diversity. At San Leandro the trend in diversity was the opposite of what would have been expected, while the numbers of animals per sample agreed with expectations. It is possible to find identical diversity indices for samples with significantly different numbers of animals. Also, populations with a few organisms evenly divided among several species would have a high diversity. For the latter reason, it is possible for an area to appear "healthy" on the basis of the diversity index when the bottom fauna is really depauperate. Using only numbers of animals has important potential drawbacks, though, since highly polluted but enriched areas often have great numbers of a few species.

Additionally, consideration must be given to the distribution of individual species in evaluating effects of pollutants. It is well known that many benthic invertebrates are not randomly distributed. Some exhibit marked preference for a particular substrate type, salinity, or dissolved oxygen. Seasonal changes in abundance of various species occur and may result in incorrect generalizations concerning a benthic community that are based on data from a single sampling period. Further, the responses to particular toxicants for most invertebrates are not known. Different species may react quite differently to any given waste; this was demonstrated by bioassays with the stickleback and other fish and invertebrates (Volume 3).

RELATIONSHIPS OF BENTHIC COMMUNITIES TO WASTE TOXICITY

Individual Sites

Diversity indices for the San Leandro cove area had a relation to relative toxicity opposite to that which was expected for theoretical reasons and opposite to that hypothesized by the U. C. Bay Study. The trends of diversity and numbers found there appear, though, to be caused by the toxic effect of the waste.

At the Standard Oil refinery the expected inverse relationship between relative toxicity and benthic species diversity was found. Again toxicity appeared to offer the best explanation for the observed effects.

While toxicity appears to offer the best explanation of effects of wastes at both San Leandro and the Standard Oil refinery, other waste characteristics cannot be ruled out with certainty, because the effects of these characteristics on invertebrates are largely unknown. At the highest waste concentrations examined, salinity at San Leandro and temperature and oxygen at Standard Oil are such that the possibility of their effect is debatable. At the outer stations in each area, their effect is quite improbable.

Thus, this study's objective of gathering evidence to determine whether a cause and effect relationship exists between toxicities of wastes and benthic community structure was partially realized. It was not fully realized because of the limited number of suitable sites found, and because at those sites which were found variables other than toxicity could not be eliminated as completely as is desirable.

The trend of diversity at San Leandro indicates that the inverse relationship between diversity and toxicity described in the Bay-Delta report is not universal. Since only two observations of this relationship were made, there is no way to determine whether this instance is an isolated exception. Quite generally accepted ecological principles and inverse relationships reported by other pollution studies (Wilhm and Dorris, 1968, Kaiser Engineers, 1969, and Warren, 1971) suggest that it is an isolated exception. In that case, the inverse diversity-waste concentration relationship might still be a useful water quality management tool in the Bay-Delta system.

The limited number of suitable sites also resulted in too few observations being made to permit a general conclusion as to whether a given toxicity concentration causes approximately the same degree of biological effect, irregardless of the actual chemical causing the toxicity. Thus a primary study objective was not achieved, but some specific observations made during the study do provide insight on the subject.

At San Leandro, effects on benthic communities were observed at waste concentrations ranging from 7.2% to 2.2%, but not at lower concentrations in the offshore area. The best estimate of the 96-hour TL_{50} for stickleback at San Leandro is .44% (Volume 3, Table 4).

Using the formula: $RTC = \frac{1000\ P}{T}$

where: RTC = relative toxicities concentration in ml/l
P = percent waste
T = TL_{50} in percent,

the range of estimate relative toxicity concentrations over which effects were observed is 165 to 50 ml/l.

At the Standard Oil site, effects were observed at waste concentrations ranging from 4.0% to 0.5%, and the mean 96-hour TL_{50} for stickleback was 80.5%. Thus, the effect of toxicity appeared to be evident at RT concentrations ranging from about 6 ml/l to 50 ml/l. The presence of San Pablo sewage treatment plant waste in this area probably would increase the values of relative toxicity from local sources to approximately 7 to 55 ml/l.

It is important to note here that the Kaiser Engineers in their Bay-Delta report (1969) concluded that "detectable damage will be done to the benthic fauna in those areas where relative toxicity is not reduced or diluted by a factor of 25". This is equivalent to 40 ml/l of relative toxicity. At Standard Oil, we were able to detect an influence of wastes on the benthos at concentrations of relative toxicity well below 40 ml/l. The limit of detectable effects at San Leandro was very similar to that identified in the Bay-Delta report.

Several factors make the results of the two studies not directly comparable. The most important of these are:

(1) The proximity of observations to the discharge point in the current study results in little time for decay of toxicities.

(2) This proximity also results in greater variations in toxicity concentrations during the tidal cycle, so the difference between maximum and mean concentrations is undoubtedly greater.

(3) The situation being observed in the current study involves the effect of one or two wastes at relatively high concentrations, while Bay-Delta analysis concerned the combined effects of many wastes at lower concentrations.

(4) In the current study effects are being differentiated against an undefined background concentration.

The first three of these factors should cause a given mean concentration in the current study to have a greater effect than the same mean in the Bay-Delta analysis. These results suggest that the limit of effects at San Leandro was at a relative toxicity concentration greater than that hypothesized as being limiting by the Bay-Delta Program. Since the observed limits at Standard Oil was lower than the Bay-Delta Program's hypothesized limit by a factor of about 6, it would probably still be lower after being corrected for the biases.

Lower San Joaquin River

Lower San Joaquin River data indicate a general trend of downstream reduction in total numbers and diversity of benthic invertebrates. These trends in benthic community characteristics are generally inversely related to trends in both relative toxicity and salinities.

Changes in other measured chemical or physical properties of the environment were not closely related to the observed benthic community trends. Hence, the results suggest that the observed trends were caused by either salinity or toxicity differences. Some doubt is introduced since neither the trend nor magnitude of benthic community characteristics changed between September and March despite the changes in salinity and toxicity. However, this could be due to benthic communities being relatively stable and responding primarily to overall annual conditions.

The data are inadequate for distinguishing the relative effects of salinity and toxicity with any degree of certainty. Trends of salinity and toxicity were too similar for relationships to be differentiated by statistical means, considering the precision and accuracy of the measurements involved.

Since toxicity probably remains quite constant downstream from Station 7 while trends in the benthic community characteristics do not change at that point, it might be argued that salinity is more important.

The U. C. Bay Study developed an equation to take into account the relationship of the benthic community diversity index to salinity and composition of the substrate. This equation is: $I_d = 0.10 + 0.096$ (chlorosity g/l) + 0.0061 (% sand) (Storrs, et al, 1969). From this equation, diversity would be expected to increase as salinity increases. If the decrease observed by us is in fact due to the changes in salinity and is not the result of waste concentration changes or some other factor, there is a discrepancy between our results and the realtionship proposed in the Bay-Delta report.

This discrepancy appears to be readily explainable on theoretical grounds. The downstream end of the San Joaquin River sampling area is situated in the part of the estuary which undergoes the greatest daily and annual fluctuations in salinity. This environment is transitional between the bay and river habitats, and therefore a relatively harsh environment. Hence, fewer species are able to survive and diversity is relatively low when compared to that in areas farther upstream or down into the Bay proper.

Thus, theoretically, a cause and effect relationship between diversity indices and salinity is reasonable in the area under consideration. On the other hand there is no general principle leading one to expect a relationship between salinity and numbers of invertebrates.

Considering all of the uncertainties the lower San Joaquin River results do not contribute any definite evidence concerning the effects of waste discharges.

V. SUMMARY AND CONCLUSIONS

This report describes a portion of the Toxicities and Biostimulation Studies designed to evaluate effects of waste discharges on benthic invertebrate communities. A general relationship was sought between the level of acute toxicity from discharges and the degree of effect on invertebrate communities.

The basic approach was to select waste discharges with dispersion zones in which waste concentrations could be defined and in which waste toxicity would be the primary variable potentially affecting benthic invertebrates. The abundance of individual invertebrate species and the diversity of the community were measured at points covering the range of waste concentrations present. Observed trends in community characteristics were then compared with toxicity concentrations calculated from acute toxicity bioassays on fish conducted in another portion of the study. In one case, additional information on invertebrate communities was gathered from communities which grew on artificial substrates.

Only two discharge sites were found in the Bay-Delta system which had characteristics reasonably compatible with the planned approach. Therefore, two additional study areas were selected to examine the combined effects of a group of waste discharges on benthic invertebrate communities over a substantial segment of the estuary. One of these areas was the lower San Joaquin River and the other was Lower and South San Francisco Bay. In the latter case, the primary purpose was to make some assessment of whether changes had occurred in invertebrate communities in response to waste discharge changes since the U. C. Bay Study. This was not possible though due to uncertainties concerning the identification of invertebrates.

On some occasions the precision of measurements of invertebrate numbers and diversity was good, with 95% confidence limits being on the order of 20% of the mean. Frequently, though, precision was considerably poorer so apparent trends were not significant statistically.

Sampling on two different occasions in the lower San Joaquin River and at the San Leandro sewage treatment plant indicated similar trends in both numbers and diversity of invertebrates. This and the similarity of communities at replicate stations with the same waste concentration indicate that sampling results are indicative of the benthic communities present. Diversity, numbers of individuals, and individual species distribution all proved important in evaluating benthic community status.

At the individual discharges studied, San Leandro sewage treatment plant and the Standard Oil refinery at Richmond, trends in benthic diversity and numbers were correlated with waste concentrations. In both cases, effects were probably, but not certainly, caused by the toxicity of the wastes.

At San Leandro effects on diversity and numbers were identifiable down to RT concentrations which were probably equivalent to a somewhat greater concentration than the 40 ml/l hypothesized by the Bay-Delta Program to be the limit causing adverse effects. At Standard Oil the comparable RT concentration was probably equivalent to a concentration lower than 40 ml/l.

A study at another site, the former Mountain Copper Company discharge at Suisun Bay, merely served to identify an area of severe degradation. The degradation is probably due to residual concentrations of heavy metals, although not enough is known about invertebrate requirements to be sure of this.

A study of benthic invertebrates in the lower San Joaquin River showed trends of decreasing invertebrate abundance and diversities from the mouth of False River to Pittsburg. These trends were related inversely to trends in salinity and waste toxicity, and information is insufficient to distinguish between effects of the two.

The principal conclusions from the study are:

INDIVIDUAL DISPERSION ZONE STUDIES

1. The individual waste discharges studied affected benthic invertebrate communities within their dispersion zones.

2. The most reasonable explanation for the observed effects on benthic invertebrate communities is that they were caused principally by the toxic character of the wastes.

3. The diversity and numbers of benthic invertebrates were inversely related to waste concentration, with the exception of a direct relationship in diversity at San Leandro. The latter is contrary to the relationship hypothesized by the Bay-Delta Program and that

expected from general ecological theory. However, the significance of this exception cannot be evaluated due to the limited number of observations.

4. Suspension of chlorination of the San Leandro waste for 30 days produced no apparent changes in the relationship of numbers or diversity of benthic invertebrates to waste concentration. This indicates that either chlorination did not affect the benthos or the 30-day cessation of chlorination was too short a time for manifestation of changes.

REGIONAL STUDIES

5. The number of waste discharges in the Bay-Delta system having dispersion zones with characteristics suitable for the approach used in this study is very limited. As a result, no such study can produce enough observations to identify general relationships between toxicity concentrations and the degree of effect on invertebrate communities.

6. Benthic invertebrate numbers and diversity are inversely related to waste concentrations in the lower San Joaquin River. They are also correlated with salinity though, so it is impossible to identify the causative factor with available evidence.

BENTHIC INVERTEBRATES AS WATER QUALITY INDICATORS

7. The similarity of communities during the two sampling periods at both San Leandro and the lower San Joaquin River reflect stability, indicating that the communities integrate environmental effects over a considerable period of time. This is valuable in evaluating long-term effects of pollution. As a result, though, invertebrate communities have limited value in evaluating short-term effects, such as the stopping of chlorination at San Leandro. Other important limitations are frequently high sampling variability and the high cost of processing samples.

8. Diversity, numbers and individual species distribution should all be considered in evaluating benthic invertebrate communities.

9. Great care must be taken to establish the correct identification of all specimens in such studies. Incorrect identifications can cause errors in the calculation of diversity indices. More important, misidentification could lead to later false conclusions that a particular species was no longer present due to water quality conditions when it was in reality present but misidentified in a previous study about environmental changes. It is

apparent that the taxonomic description of invertebrates in San Francisco Bay and the availability of taxonomists with the necessary expertise are such that a much greater effort than was possible in the current study would be required to describe environmental effects thoroughly based on the distribution of invertebrate communities.

LITERATURE CITED

Connell, J. and E. Orias. 1964. The ecological regulations of species diversity. The American Naturalist, 98:399-414.

Filice, F. P. 1954a. An ecological survey of the Castro Creek area in San Pablo Bay. Wasmann Journal of Biology, 12:1-24.

_____ 1954b. A study of some factors affecting the bottom fauna of a portion of the San Francisco Bay estuary. Wasmann Journal of Biology, 12:257-298.

_____ 1958. Invertebrates from the estuarine portion of San Francisco Bay and some factors influencing their distributions. Wasmann Journal of Biology, 16:159-211.

_____ 1959. The effect of wastes on the distribution of bottom invertebrates in the San Francisco Bay estuary. Wasmann Journal of Biology, 17:1-17.

Hutchinson, G. E. 1953. Concept of pattern in ecology. Proceedings of the Academy of Natural Sciences, Philadelphia, 105:1-12.

Kaiser, Engineers. 1969. "Final Report-San Francisco Bay-Delta Water Quality Control Program".

Margalef, D. R. 1956. Informacion y diversiadad especifica en las conunidades de organismos, Invest. Pesq. 3:99-106.

Mason, W., J. B. Anderson, R. D. Kreis, and W. C. Johnson. Artificial substrate sampling, macroinvertebrates in a polluted reach of the Klamath River, Oregon. Journal of Water Pollution Control Federation, 42:315-328.

McCarty, J., R. Wagner, M. Macomber, H. Harris, M. Stephenson, and E. Pearson. Appendixes to an investigation of water and sediment quality and pollutional characteristics of three areas in San Francisco Bay 1960-61. June 1962 Sanitary Engineering Research Laboratory, College of Engineering, University of California, Berkeley.

Painter, R. 1966. California Department of Fish and Game, "Ecological studies of the Sacramento-San Joaquin Estuary, Part 1", Fish Bull. 133:40-56.

Patten, B. C. 1962. Species diversity in net phytoplankton of Raritan Bay. Journal of Marine Research, 20:57-75.

Pielou, E. C. 1966. Species-diversity and pattern-diversity in the study of ecological succession, Journal of Theoretical Biology, 10:370-383.

Storrs, P. N., E. A. Pearson, and R. E. Selleck. 1969. "Final Report Vol. 6 - Water and Sediment Quality and Waste Discharge Relationships", a comprehensive study of San Francisco Bay, SERL report no. 67-4, Sanitary Engineering Research Laboratory, University of California, Berkeley.

Wilhm, J. L. and T. C. Dorris, 1961. Biological parameters for water quality criteria. Bioscience, 18:477-481.

BENTHIC ANIMALS, STANDARD OIL

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C) a/	Ph.	E.C. a/	D.O. (ppm) a/
STATION 1 -- SAMPLE A		10	7.5	7.8	205	9.5
ARTHROPODA						
Ampelisca sp.	1,350					
Corophium sp.	11					
Synidotea laticauda	1					
MOLLUSCA						
Mya arenaria	59					
Modiolus sp.	4					
Tapes semidecussata	1					
ANNELIDA						
Polychaeta unid.	29					
Oligocheata						
Tubificids	23					
Total	1,478	D.I. = 0.39				
STATION 1 -- SAMPLE B						
ARTHROPODA						
Ampelis sp.	751					
Corophium sp.	6					
MOLLUSCA						
Odostomia sp.	1					
Mya arenaria	33					
Gemma gemma	2					
Modiolus sp.	1					
Nassarius sp.	1					
ANNELIDA						
Polychaeta unid.	10					
Oligochaeta						
Tubificids	2					
NEMERTEA	1					
Total	808	D.I. = 0.31				
STATION 1 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	1,207					
Corophium sp.	2					
Cumacea	3					
Leptochelia sp.	17					

a/ E.C., D. O. and Temp. values are for high slack tide

APPENDIX A-1

BENTHIC ANIMALS, STANDARD OIL

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	Ph.	E.C.	D.O. (ppm)
MOLLUSCA						
Modiolus sp.	12					
Mya arenaria	43					
Macoma sp.	3					
Nassarius sp.	1					
ANNELIDA						
Polychaeta unid.	11					
Streblospio benedicti	25					
Oligochaeta						
Tubificids	127					
Total	1,451	D.I. = 0.69				
STATION 2 -- SAMPLE A		10	8.4	7.9	235	9.2
			.		.	.
			.		.	.
			8.1		198	9.4
ARTHROPODA						
Ampelisca sp.	7					
Corophium sp.	28					
MOLLUSCA						
Mya arenaria	13					
Gemma gemma	386					
Odostomia sp.	1					
ANNELIDA						
Polychaeta unid.	34					
Streblospio benedicti	983					
Oligochaeta						
Tubificids	54					
Total	1,506	D.I. = 0.96				
STATION 2 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	1					
Corophium sp.	7					
Leptochelia sp.	23					
MOLLUSCA						
Gemma gemma	297					
Mya arenaria	17					
Nassarius sp.	3					
ANNELIDA						
Streblospio benedicti	1,362					
Polychaeta unid.	23					
Oligochaeta						
Tubificids	268					
Total	2,001	D.I. = 0.97				

APPENDIX A-1

BENTHIC ANIMALS, STANDARD OIL

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	Ph.	E.C.	D.O. (ppm)
STATION 2 -- SAMPLE C						
ARTHROPODA						
Corophium sp.	19					
MOLLUSCA						
Gemma gemma	354					
Mya arenaria	31					
ANNELIDA						
Polychaeta, unid.	33					
Streblospio benedicti	720					
Oligochaeta						
Tubificids	214					
Total	1,371	D.I. = 1.20				
STATION 3 -- SAMPLE A						
		8	7.8	7.9	221	9.2
			.		.	.
			9.4		189	8.4
ARTHROPODA						
Corophium sp.	5					
Ampelisca sp.	1					
MOLLUSCA						
Mya arenaria	3					
Gemma gemma	3					
ANNELIDA						
Polychaeta unid.	123					
Streblospio benedicti	3,981					
Oligochaeta						
Tubificids	1,046					
Total	5,162	D.I. = 0.61				
STATION 3 -- SAMPLE B						
MOLLUSCA						
Gemma gemma	366					
Macoma sp.	2					
Mya arenaria	33					
ANNELIDA						
Polychaeta unid.	95					
Streblospio benedicti	4,321					
Oligochaeta						
Tubificids	1,262					
Total	6,079	D.I. = 0.82				

APPENDIX A-1

BENTHIC ANIMALS, STANDARD OIL

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	Ph.	E.C.	D.O. (ppm)
STATION 3 -- SAMPLE C						
ARTHROPODA						
Corophium sp.	6					
Leptochelia sp.	1					
MOLLUSCA						
Gemma gemma	280					
ANNELIDA						
Streblospio benedicti	5,179					
Polychaeta unid.	75					
Oligochaeta						
Tubificids	1,490					
Polydora uncata	4					
NEMATODA	1					
Total	7,036	D.I. = 0.72				
STATION 4 -- SAMPLE A		3	14.9 . . 16.1	7.6	242 . . 258	5.15 . . 0.28
ANNELIDA						
Polychaeta unid.	4					
Oligochaeta	23					
Total	27	D.I. = 0.42				
STATION 4 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	1					
ANNELIDA						
Streblospio benedicti	1					
Oligochaeta	8					
Total	10	D.I. = 0.64				
STATION 4 -- SAMPLE C						
MOLLUSCA						
Gemma gemma	1					
ANNELIDA						
Streblospio benedicti	1					
Polychaeta unid.	1					
Oligochaeta unid.	35					
Total	38	D.I. = 0.36				

APPENDIX A-1

BENTHIC ANIMALS, STANDARD OIL

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	Ph.	E.C.	D.O. (ppm)
STATION 4 -- SAMPLE D						
MOLLUSCA						
Gemma gemma	1					
Mya arenaria	1					
ANNELIDA						
Oligochaeta unid.	32					
Total	34	D.I. = 0.26				
STATION 5 -- SAMPLE A		4	7.9	7.6	248	9.0
			.		.	.
			.		.	.
			10.9		206	6.0
ARTHROPODA						
Corophium sp.	137					
MOLLUSCA						
Mya arenaria	22					
Gemma gemma	106					
ANNELIDA						
Polychaeta unid.	62					
Streblospio benedicti	1,509					
Oligochaeta						
Tubificids	210					
Total	2,046	D.I. = 1.03				
STATION 5 -- SAMPLE B						
ARTHROPODA						
Corophium sp.	585					
MOLLUSCA						
Gemma gemma	292					
Mya arenaria	63					
Macoma sp.	12					
ANNELIDA						
Polychaeta unid.	175					
Streblospio benedicti	3,401					
Oligochaeta						
Tubificids	1,528					
Total	6,056	D.I. = 1.19				
STATION 5 -- SAMPLE C						
ARTHROPODA						
Corophium sp.	76					

APPENDIX A-1

BENTHIC ANIMALS, STANDARD OIL

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	Ph.	E.C.	D.O. (ppm)
MOLLUSCA						
Macoma sp.	10					
Gemma gemma	94					
Mya arenaria	9					
ANNELIDA						
Streblospio benedicti	2,091					
Polychaeta unid.	70					
Oligochaeta unid.	8					
Tubificids	858					
Total	3,216	D.I. = 0.86				
STATION 6 -- SAMPLE A		4	8.6	7.8	296	8.8
			.		.	.
			.		.	.
			8.3		214	9.6
ARTHROPODA						
Ampelisca sp.	4					
Corophium sp.	16					
MOLLUSCA						
Modiolus sp.	1					
Mya arenaria	112					
Gemma gemma	472					
ANNELIDA						
Polychaeta unid.	25					
Streblospio benedicti	1,840					
Oligochaeta						
Tubificids	83					
Total	2,553	D.I. = 0.87				
STATION 6 -- SAMPLE B						
ARTHROPODA						
Corophium sp.	1					
MOLLUSCA						
Mya arenaria	30					
Gemma gemma	205					
ANNELIDA						
Streblospio benedicti	54					
Polychaeta unid.	1					
Oligochaeta						
Tubificids	14					
Total	305	D.I. = 0.97				

APPENDIX A-1

BENTHIC ANIMALS, STANDARD OIL

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	Ph.	E.C.	D.O. (ppm)
STATION 6 --SAMPLE C						
ARTHROPODA						
Corophium sp.	20					
MOLLUSCA						
Gemma gemma	450					
Mya arenaria	85					
Macoma sp.	1					
ANNELIDA						
Polychaeta unid.	43					
Streblospio benedicti	1,282					
Oligochaeta						
Tubificids	119					
Total	2,000	D.I. = 1.05				
STATION 7 -- SAMPLE A		4	8.7	7.8	303	8.7
			.		.	.
			.		.	.
			10.0		222	7.4
ARTHROPODA						
Ampelisca sp.	20					
Corophium sp.	41					
MOLLUSCA						
Gemma gemma	125					
Mya arenaria	43					
Odostomia sp.	1					
ANNELIDA						
Polychaeta unid.	33					
Streblospio benedicti	466					
Oligochaeta						
Tubificids	148					
Total	877	D.I. = 1.41				
STATION 7 -- SAMPLE B						
ARTHROPODA						
Corophium sp.	136					
Ampelisca sp.	25					
MOLLUSCA						
Mya arenaria	116					
Gemma gemma	221					
ANNELIDA						
Polychaeta unid.	32					
Streblospio benedicti	487					
Oligochaeta						
Tubificids	73					
Total	1,090	D.I. = 1.54				

APPENDIX A-1

BENTHIC ANIMALS, STANDARD OIL

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	Ph.	E.C.	D.O. (ppm)
STATION 7 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	18					
Corophium sp.	164					
MOLLUSCA						
Mya arenaria	163					
Gemma gemma	306					
ANNELIDA						
Polychaeta unid.	33					
Streblospio benedicti	687					
Oligochaeta						
Tubificids	89					
Total	1,460	D.I. = 1.47				
STATION 8 -- SAMPLE A		1	8.1	7.9	258	9.1
			.		.	.
			.		.	.
			8.6		212	9.4
ARTHROPODA						
Corophium sp.	571					
Ampelisca sp.	9					
MOLLUSCA						
Gemma gemma	2,120					
Mya arenaria	210					
ANNELIDA						
Polichaeta unid.	63					
Streblospio benedicti	1,348					
Oligochaeta						
Tubificids	382					
Total	4,703	D.I. = 1.37				

BENTHIC ANIMALS, MOUNTAIN COPPER
June 21, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	CL^- (ppm)	D.O. (ppm)
STATION 1 -- SAMPLE A		4	--	7.9	720	7.7
ANNELIDA						
Oligochaeta unid.	1					
Total	1					
STATION 1 -- SAMPLE B						
ANNELIDA						
Oligochaeta unid.	1					
Total	1					
STATION 1 -- SAMPLE C						
MOLLUSCA						
Mya arenaria	4					
ANNELIDA						
Oligochaeta unid.	4					
Polychaeta unid.	1					
Total	9					
STATION 2 -- SAMPLE A		6	--	7.9	600	8.7
ANNELIDA						
Oligochaeta unid.	7					
Total	7					
STATION 2 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	1					
MOLLUSCA						
Mya arenaria	2					
Total	3					
STATION 2 -- SAMPLE C						
MOLLUSCA						
Mya arenaria	2					
Total	2					

APPENDIX A-2

BENTHIC ANIMALS, MOUNTAIN COPPER
June 21, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	Cl^- (ppm)	D.O. (ppm)
STATION 3 -- SAMPLE A		6	--	8.1	720	8.2
ANNELIDA						
Oligochaeta unid.	1					
Total	1					
STATION 3 -- SAMPLE B						
No animals	0					
STATION 3 -- SAMPLE C						
ANNELIDA						
Oligochaeta unid.	3					
Total	3					
STATION 4 -- SAMPLE A		4	--	8.2	780	8.3
No animals	0					
STATION 4 -- SAMPLE B						
No animals	0					
STATION 4 -- SAMPLE C						
ANNELIDA						
Polychaeta unid.	1					
Total	1					
STATION 5 -- SAMPLE A		6	--	8.2	600	8.5
MOLLUSCA						
Mya arenaria	1					
ANNELIDA						
Polychaeta unid.	1					
Nereis sp.	1					
Total	3					
STATION 5 -- SAMPLE B						
ANNELIDA						
Nereis sp.	3					
Oligochaeta unid.	3					
Total	6					

APPENDIX A-2

BENTHIC ANIMALS, MOUNTAIN COPPER
June 21, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	CL^- (ppm)	D.O. (ppm)
STATION 5 -- SAMPLE C						
ANNELIDA						
Oligochaeta unid.	9					
Polychaeta unid.	4					
MOLLUSCA						
Mya arenaria	4					
Total	17					
STATION 6 -- SAMPLE A		4	--	7.8	720	8.4
ANNELIDA						
Oligochaeta unid.	2					
Polychaeta unid.	1					
Total	3					
STATION 6 -- SAMPLE B						
ANNELIDA						
Polychaeta unid.	4					
Oligochaeta	2					
Nereis sp.	1					
MOLLUSCA						
Mya arenaria	4					
ARTHROPODA						
Isopoda unid.	2					
Total	13					
STATION 6 -- SAMPLE C						
ANNELIDA						
Nereis sp.	4					
Oligochaeta unid.	11					
Total	15					
STATION 7 -- SAMPLE A		6	--	8.0	720	8.6
ANNELIDA						
Oligochaeta unid.	14					
Total	14					

APPENDIX A-2

BENTHIC ANIMALS, MOUNTAIN COPPER
June 21, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	CL^- (ppm)	D.O. (ppm)
STATION 7 -- SAMPLE B						
ANNELIDA						
Oligochaeta unid.	8					
Total	8					
STATION 7 -- SAMPLE C						
ANNELIDA						
Oligochaeta unid.	6					
Total	6					
STATION 8 -- SAMPLE A		4	--	8.0	720	8.2
ANNELIDA						
Oligochaeta unid.	317					
Total	317					
STATION 8 -- SAMPLE B						
ANNELIDA						
Oligochaeta unid.	263					
ARTHROPODA						
Corophium sp.	1					
Total	264					
STATION 8 -- SAMPLE C						
ANNELIDA						
Oligochaeta unid.	341					
Total	341					

BENTHIC ANIMALS, SAN LEANDRO
October 30, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 107 -- SAMPLE A		6	14	6.9	446	8.6
ARTHROPODA						
Corophium sp.	8					
Hemigrapsus oregonensis	3					
MOLLUSCA						
Ostrea lurida	186					
Crepidula perforans	193					
Gemma gemma	1					
Amphissa sp.	18					
ANNELIDA						
Streblospio benedicti	4					
Polychaeta unid.	118					
Oligochaeta unid.	170					
CNIDARIA						
Metridium senile	18					
Total	719	D.I. = 1.62				
STATION 107 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	14					
Corophium sp.	179					
MOLLUSCA						
Tapes semidecussata	1					
Crepidula perforans	4					
Modiolus sp.	1					
Ostrea lurida	8					
ANNELIDA						
Streblospio benedicti	1					
Polychaeta unid.	109					
Oligochaeta unid.	214					
Total	531	D.I. = 1.26				
STATION 107 -- SAMPLE C						
ARTHROPODA						
Corophium sp.	311					
Ampelisca sp.	49					
Synidotea laticauda	4					

APPENDIX A-3

BENTHIC ANIMALS, SAN LEANDRO
October 30, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
MOLLUSCA						
Ostrea lurida	31					
Tapes semidecussata	1					
Modiolus sp.	1					
Crepidula perforans	13					
ANNELIDA						
Streblospio benedicti	1					
Polychaeta unid.	70					
Oligochaeta unid.	549					
NEMATODA	14					
CNIDARIA						
Metridium senile	4					
Total	1,152	D.I. = 1.24				
STATION 108 -- SAMPLE A		6	13.8	6.9	456	8.6
ARTHROPODA						
Corophium sp.	41					
Ampelisca sp.	15					
Hemigrapsus oregonensis	4					
MOLLUSCA						
Ostrea lurida	226					
Tapes semidecussata	4					
Crepidula perforans	9					
Modiolus sp.	1					
ANNELIDA						
Polychaeta unid.	318					
Oligochaeta						
Tubificids	15					
Oligochaeta unid.	410					
Total	1,043	D.I. = 1.38				
STATION 108 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	27					
Corophium sp.	36					
Synidotea laticauda	1					
MOLLUSCA						
Ostrea lurida	9					
Crepidula perforans	2					
Tapes semidecussata	1					
ANNELIDA						
Polychaeta unid.	185					
Oligochaeta unid.	191					
NEMATODA	3					

APPENDIX A-3

BENTHIC ANIMALS, SAN LEANDRO
October 30, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
CNIDARIA						
Metridium senile	3					
Total	558	D.I. = 1.17				
STATION 108 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	70					
Corophium sp.	182					
Synidotea laticauda	2					
Hemigrapsus oregonensis	3					
MOLLUSCA						
Crepidula perforans	5					
Ostrea lurida	8					
ANNELIDA						
Polychaeta unid.	247					
Oligochaeta unid.	485					
Total	1,002	D.I. = 1.26				
STATION 84 -- SAMPLE A		6	14.2	6.7	445	8.6
ARTHROPODA						
Corophium sp.	25					
Ampelisca sp.	88					
MOLLUSCA						
Ostrea lurida	38					
Crepidula perforans	3					
Gemma gemma	1					
ANNELIDA						
Polychaeta unid.	91					
Oligochaeta unid.	224					
Total	470	D.I. = 1.38				
STATION 84 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	78					
Corophium sp.	36					
Synidotea laticauda	3					
MOLLUSCA						
Ostrea lurida	31					
Crepidula perforans	4					
Tapes semidecussata	1					
ANNELIDA						
Streblospio benedicti	6					
Polychaeta unid.	95					
Oligochaeta	213					
Total	467	D.I. = 1.49				

APPENDIX A-3

BENTHIC ANIMALS, SAN LEANDRO
October 30, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 84 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	74					
Corophium sp.	20					
Synidotea laticauda	2					
Hemigrapsus oregonensis	1					
Balanus sp.	5					
MOLLUSCA						
Crepidula perforans	14					
Ostrea lurida	37					
ANNELIDA						
Polychaeta unid.	34					
Oligochaeta unid.	44					
Total	231	D.I. = 1.77				
STATION 112 -- SAMPLE A		6	14.2	6.7	434	7.1
ARTHROPODA						
Ampelisca sp.	22					
Synidotea laticauda	2					
Balanus sp.	2					
Hemigrapsus oregonensis	1					
MOLLUSCA						
Modiolus sp.	1					
Mya arenaria	1					
Tapes semidecussata	1					
Ostrea lurida	1					
ANNELIDA						
Polychaeta unid.	197					
Oligochaeta						
Tubificids	83					
Oligochaeta unid.	281					
Total	592	D.I. = 1.19				
STATION 112 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	17					
Corophium sp.	18					
Synidotea laticauda	5					
Hemigrapsus oregonensis	2					

APPENDIX A-3

BENTHIC ANIMALS, SAN LEANDRO
October 30, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
MOLLUSCA						
Modiolus sp.	1					
Tapes semidecussata	6					
Ostrea lurida	8					
Crepidula perforans	1					
ANNELIDA						
Polychaeta	260					
Oligochaeta	654					
Oligochaeta						
Tubificids	38					
Total	1,010	D.I. = 0.97				
STATION 112 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	16					
Corophium sp.	18					
Hemigrapsus oregonensis	1					
Synidotea laticauda	2					
Balanus sp.	1					
MOLLUSCA						
Ostrea lurida	12					
Tapes semidecussata	2					
Crepidula perforans	11					
ANNELIDA						
Polychaeta unid.	224					
Oligochaeta unid.	1,149					
NEMATODA	11					
Total	1,447	D.I. = 0.69				
STATION 85 -- SAMPLE A		6	14.2	6.8	442	8.2
ARTHROPODA						
Ampelisca sp.	2,044					
Corophium sp.	50					
Synidotea laticauda	5					
MOLLUSCA						
Gemma gemma	1,161					
Modiolus sp.	16					
ANNELIDA						
Streblospio benedicti	86					
Polychaeta unid.	54					
Oligochaeta						
Tubificids	12					
Total	3,428	D.I. = 0.96				

APPENDIX A-3

BENTHIC ANIMALS, SAN LEANDRO
October 30, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 85 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	2,004					
Corophium sp.	92					
Leptochelia sp.	1					
Cumacea	1					
MOLLUSCA						
Gemma gemma	853					
Mya arenaria	1					
Corbicula manilensis	5					
Modiolus sp.	6					
ANNELIDA						
Streblospio benedicti	122					
Polychaeta unid.	120					
Oligochaeta unid.	16					
Oligochaeta Tubificids	49					
CHORDATA						
Ascidea cereatodes	1					
NEMATODA	6					
Total	3,277	D.I. = 1.09				
STATION 85 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	2,590					
Corophium sp.	68					
Synidotea laticauda	8					
MOLLUSCA						
Modiolus sp.	10					
Gemma gemma	1,379					
ANNELIDA						
Streblospio benedicti	66					
Polychaeta unid.	81					
Oligochaeta unid.	17					
Total	4,219	D.I. = 0.91				
STATION 73 -- SAMPLE A		6	13.8	6.8	438	7.8
ARTHROPODA						
Ampelisca sp.	778					
Corophium sp.	12					
Synidotea laticauda	4					

APPENDIX A-3

BENTHIC ANIMALS, SAN LEANDRO
October 30, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
MOLLUSCA						
Gemma gemma	661					
Mya arenaria	8					
Modiolus sp.	2					
ANNELIDA						
Streblospio benedicti	91					
Polychaeta unid.	22					
Oligochaeta unid.	15					
Oligochaeta Tubificids	9					
CHORDATA						
Ascidea cereatodes	2					
Total	1,604	D.I. = 1.08				

STATION 73 -- SAMPLE B

ARTHROPODA						
Ampelisca sp.	676					
Corophium sp.	25					
Synidotea laticauda	1					
MOLLUSCA						
Gemma gemma	286					
Modiolus sp.	4					
Mya arenaria	8					
ANNELIDA						
Streblospio benedicti	203					
Polychaeta unid.	36					
Oligochaeta unid.	22					
Oligochaeta Tubificids	27					
CHORDATA						
Ascidea cereatodes	1					
Total	1,339	D.I. = 1.31				

STATION 73 -- SAMPLE C

ARTHROPODA						
Ampelisca sp.	884					
Corophium sp.	51					
Synidotea laticauda	2					
MOLLUSCA						
Gemma gemma	371					
Modiolus sp.	6					
Macoma sp.	1					
Mya arenaria	8					

APPENDIX A-3

BENTHIC ANIMALS, SAN LEANDRO
October 30, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
ANNELIDA						
Streblospio benedicti	181					
Polychaeta unid.	70					
Oligochaeta unid.	51					
Oligochaeta Tubificids	21					
NEMATODA	1					
Total	1,647	D.I. = 1.35				
STATION 61 -- SAMPLE A		6	13.5	6.5	432	7.8
ARTHROPODA						
Ampelisca sp.	1,003					
Corophium sp.	21					
MOLLUSCA						
Gemma gemma	245					
Mya arenaria	1					
Modiolus sp.	1					
Tapes semidecussata	1					
ANNELIDA						
Streblospio benedicti	323					
Polychaeta unid.	37					
CHORDATA						
Ascidea ceretodes	4					
NEMATODA	1					
Total	1,637	D.I. = 1.05				
STATION 61 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	645					
Corophium sp.	16					
MOLLUSCA						
Gemma gemma	89					
Mya arenaria	3					
ANNELIDA						
Streblospio benedicti	126					
Polychaeta unid.	39					
Oligochaeta unid.	10					
Oligochaeta Tubificids	62					
CHORDATA						
Ascidea cereatodes	1					
NEMATODA	3					
Total	994	D.I. = 1.21				

APPENDIX A-3

BENTHIC ANIMALS, SAN LEANDRO
October 30, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 61 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	740					
Corophium sp.	11					
MOLLUSCA						
Gemma gemma	107					
Modiolus sp.	3					
ANNELIDA						
Streblospio benedicti	248					
Polychaeta unid.	34					
Oligochaeta unid.	23					
Oligochaeta Tubificids	130					
Total	1,296	D.I. = 1.28				
STATION 98 -- SAMPLE A		6	13.4	6.6	427	7.4
ARTHROPODA						
Ampelisca sp.	369					
Corophium sp.	18					
MOLLUSCA						
Nassarius sp.	1					
Modiolus sp.	2					
Mya arenaria	38					
Gemma gemma	148					
ANNELIDA						
Streblospio benedicti	504					
Polychaeta unid.	38					
Oligochaeta unid.	2					
Oligochaeta Tubificids	164					
Total	1,284	D.I. = 1.51				
STATION 98 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	68					
MOLLUSCA						
Mya arenaria	15					
Gemma gemma	137					
ANNELIDA						
Streblospio benedicti	210					
Polychaeta unid.	8					
Oligochaeta unid.	6					
Oligochaeta Tubificids	194					
Total	638	D.I. = 1.47				

APPENDIX A-3

BENTHIC ANIMALS, SAN LEANDRO

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 98 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	283					
Corophium sp.	12					
MOLLUSCA						
Gemma gemma	254					
Mya arenaria	53					
Nassarius sp.	1					
Macoma sp.	18					
ANNELIDA						
Streblospio benedicti	339					
Polychaeta unid.	77					
Oligochaeta unid.	22					
Oligochaeta Tubificids	182					
NEMATODA	1					
Total	1,232	D.I. = 1.78				

APPENDIX A-4

BENTHIC ANIMALS, SAN LEANDRO
April 30, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 85a -- SAMPLE A			14	80	363	3.6
ARTHROPODA						
Ampelisca sp.	917					
Corophium sp.	332					
Cumacea	1					
MOLLUSCA						
Gemma gemma	250					
Modiolus sp.	14					
Macoma sp.	1					
Mya arenaria	1					
ANNELIDA						
Polychaeta unid.	11					
Streblospio benedicti	11					
Oligochaeta						
Tubificids	119					
NEMATODA	3					
Total	1,660	D.I. = 1.22				
STATION 85a -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	2,554					
Corophium sp.	250					
Cumacea	8					
Leptochelia sp.	7					
MOLLUSCA						
Gemma gemma	263					
Modiolus sp.	13					
ANNELIDA						
Polychaeta unid.	122					
Streblospio benedicti	123					
Oligochaeta						
Tubificids	198					
NEMATODA	21					
Total	3,559	D.I. = 1.06				
STATION 85a -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	872					
Corophium sp.	180					
MOLLUSCA						
Gemma gemma						
Tapes semidecussata	256					
Mya arenaria	2					
Modiolus sp.	8					

APPENDIX A-4

BENTHIC ANIMALS, SAN LEANDRO
April 30, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
ANNELIDA						
Streblospio benedicti	12					
Polychaeta unid.	12					
Oligochaeta						
Tubificids	63					
NEMATODA	2					
Total	1,407	D.I. = 1.12				
STATION 85b -- SAMPLE A			14	8.0	363	3.6
ARTHROPODA						
Ampelisca sp.	1,235					
Corophium sp.	201					
MOLLUSCA						
Gemma gemma	267					
Modiolus sp.	17					
ANNELIDA						
Streblospio benedicti	17					
Polychaeta unid.	20					
Oligochaeta						
Tubificids	116					
NEMATODA	11					
Total	1,871	D.I. = 1.12				
STATION 85b -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	823					
Corophium sp.	180					
MOLLUSCA						
Gemma gemma	241					
Modiolus sp.	3					
ANNELIDA						
Polychaeta unid.	9					
Streblospio benedicti	19					
Oligochaeta						
Tubificids	59					
NEMATODA	5					
Total	1,339	D.I. = 1.13				
STATION 85b -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	470					
Corophium sp.	45					

APPENDIX A-4

BENTHIC ANIMALS, SAN LEANDRO
April 30, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
MOLLUSCA						
Gemma gemma	101					
Modiolus sp.	1					
ANNELIDA						
Polychaeta unid	5					
Oligochaeta						
Tubificids	32					
Total	667	D.I. = 0.97				
STATION 73 -- SAMPLE A			14	7.9	363	5.4
ARTHROPODA						
Ampelisca sp.	744					
Corophium sp.	110					
Cumacea	5					
MOLLUSCA						
Modiolus sp.	4					
Macoma sp.	1					
Gemma gemma	120					
Mya arenaria	1					
ANNELIDA						
Polychaeta unid.	2					
Total	987	D.I. = 0.78				
STATION 73 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	269					
Corophium sp.	41					
Cumacea	1					
ANNELIDA						
Oligochaeta						
Tubificids	2					
MOLLUSCA						
Gemma gemma	28					
Total	341	D.I. = 0.68				
STATION 73 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	311					
Corophium sp.	89					
Cumacea	2					
MOLLUSCA						
Gemma gemma	49					

APPENDIX A-4

BENTHIC ANIMALS, SAN LEANDRO
April 30, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
ANNELIDA						
Polychaeta unid.	31					
Oligochaeta						
Tubificids	19					
Total	501	D.I. = 1.14				
STATION 2 -- SAMPLE A			14	8.0	353	3.2
ARTHROPODA						
Ampelisca sp.	714					
Corophium sp.	59					
Cumacea	3					
MOLLUSCA						
Macoma sp.	3					
Modiolus sp.	1					
Gemma gemma	4					
Mya arenaria	1					
ANNELIDA						
Streblospio benedicti	73					
Polychaeta unid.	11					
Oligochaeta						
Tubificids	134					
NEMATODA	5					
Total	1,008	D.I. = 0.97				
STATION 2 -- SAMPLE B						
ARTHROPODA						
Corophium sp.	164					
Ampelisca sp.	2,270					
Cumacea	7					
MOLLUSCA						
Gemma gemma	2					
Modiolus sp.	1					
ANNELIDA						
Streblospio benedicti	63					
Polychaeta unid.	33					
Oligochaeta						
Tubificids	340					
NEMATODA	4					
Total	2,884	D.I. = 0.74				
STATION 2 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	1,182					
Corophium sp.	146					
Cumacea	4					

APPENDIX A-4

BENTHIC ANIMALS, SAN LEANDRO
April 30, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
MOLLUSCA						
Gemma gemma	8					
Odostomia sp.	1					
Mya arenaria	5					
Modiolus sp.	1					
Macoma sp.	6					
ANNELIDA						
Streblospio benedicti	39					
Polychaeta unid.	17					
Oligochaeta						
Tubificids	248					
NEMATODA	2					
Total	1,659	D.I. = 0.94				
STATION 61 -- SAMPLE A			14	8.0	363	2.2
ARTHROPODA						
Ampelisca sp.	390					
Corophium sp.	98					
MOLLUSCA						
Nassarius sp.	1					
Odostomia sp.	1					
Mya arenaria	2					
Modiolus sp.	8					
Gemma gemma	155					
ANNELIDA						
Polychaeta unid.	24					
Total	679	D.I. = 1.12				
STATION 61 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	567					
Corophium sp.	128					
Cumacea	1					
MOLLUSCA						
Gemma gemma	112					
Mya arenaria	6					
Modiolus sp.	9					
Odostomia sp.	1					
Macoma sp.	2					
ANNELIDA						
Polychaeta unid.	6					
Streblospio benedicti	7					
Oligochaeta						
Tubificids	56					
NEMATODA	2					
Total	897	D.I. = 1.17				

APPENDIX A-4

BENTHIC ANIMALS, SAN LEANDRO
April 30, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 61 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	1,401					
Corophium sp.	191					
Cumacea	6					
Synidotea sp.	1					
MOLLUSCA						
Gemma gemma	88					
Modiolus sp.	8					
Mya arenaria	5					
Odostomia sp.	1					
ANNELIDA						
Streblospio benedicti	5					
Polychaeta unid.	27					
Oligochaeta						
Tubificids	113					
Total	1,846	D.I. = 0.88				
STATION 98a -- SAMPLE A			14	8.0	363	3.6
ARTHROPODA						
Ampelisca	598					
Corophium sp.	11					
Leptochelia sp.	1					
Cumacea	4					
MOLLUSCA						
Gemma gemma	54					
Macoma sp.	3					
Mya arenaria	2					
Modiolus sp.	1					
ANNELIDA						
Polychaeta unid.	123					
Streblospio benedicti	199					
Oligochaeta						
Tubificids	544					
NEMATODA						
Total	1,643	D.I. = 1.52				
STATION 98a -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	416					
Corophium sp.	8					
MOLLUSCA						
Gemma gemma	99					

APPENDIX A-4

BENTHIC ANIMALS, SAN LEANDRO
April 30, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
ANNELIDA						
Polychaeta unid.	26					
Oligochaeta						
Tubificids	175					
NEMATODA	59					
Total	783	D.I. = 2.11				
STATION 98a -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	939					
Corophium sp.	40					
Cumacea	28					
MOLLUSCA						
Gemma gemma	175					
Mya arenaria	5					
Macoma sp.	5					
Modiolus sp.	1					
ANNELIDA						
Streblospio benedicti	139					
Polychaeta unid.	76					
Oligochaeta						
Tubificids	540					
NEMATODA	49					
Total	1,997	D.I. = 1.48				
STATION 98b -- SAMPLE A			14	8.0	363	3.6
ARTHROPODA						
Ampelisca sp.	807					
Corophium sp.	7					
Cumacea	27					
MOLLUSCA						
Gemma gemma	273					
Mya arenaria	7					
Modiolus sp.	4					
Macoma sp.	1					
ANNELIDA						
Streblospio benedicti	138					
Polychaeta unid.	97					
NEMATODA	508					
Total	1,869	D.I. = 1.44				

APPENDIX A-4

BENTHIC ANIMALS, SAN LEANDRO
April 30, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 98b -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	701					
Corophium sp.	20					
Cumacea	7					
MOLLUSCA						
Gemma gemma	58					
Mya arenaria	1					
Macoma sp.	5					
ANNELIDA						
Streblospio benedicti	72					
Polychaeta unid.	64					
Oligochaeta						
Tubificids	210					
NEMATODA	6					
Total	1,144	D.I. = 1.24				
STATION 98b -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	527					
Corophium sp.	29					
Cumacea	1					
MOLLUSCA						
Modiolus sp.	3					
Macoma sp.	4					
Mya arenaria	7					
Gemma gemma	124					
ANNELIDA						
Streblospio benedicti	7					
Polychaeta unid.	29					
Oligochaeta						
Tubificids	91					
NEMATODA	52					
Total	874	D.I. = 1.34				

APPENDIX A-5

ARTIFICIAL SUBSTRATE, SAN LEANDRO

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 73 -- SAMPLE A						
ARTHROPODA						
Corophium sp.	1,844					
Ampelisca sp.	16					
Gnorimosphaeroma oregonensis	1					
MOLLUSCA						
Nassarius sp.	15					
Gemma gemma	5					
Crepidula perforans	1					
Gastropoda unid.	3					
ANNELIDA						
Oligochaeta Tubificids	1					
Total	1,886	D.I. = 0.11				
STATION 61 -- SAMPLE A						
ARTHROPODA						
Corophium sp.	1,327					
Gnorimosphaeroma oregonensis	2					
Ampelisca sp.	6					
MOLLUSCA						
Modiolus sp.	3					
Gemma gemma	1					
Total	1,339	D.I. = 0.05				
STATION 61 -- SAMPLE B						
ARTHROPODA						
Corophium sp.	937					
Ampelisca sp.	9					
Gnorimosphaeroma oregonensis	1					
MOLLUSCA						
Modiolus sp.	1					
ANNELIDA						
Polydora uncata	1					
Polychaeta unid.	2					
Total	951	D.I. = 0.09				

APPENDIX A-5

ARTIFICIAL SUBSTRATE, SAN LEANDRO

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 98 -- SAMPLE A						
ARTHROPODA						
Ampelisca sp.	1					
Corophium sp.	236					
MOLLUSCA						
Modiolus sp.	3					
Total	240	D.I. = 0.91				
STATION 98 -- SAMPLE B						
ARTHROPODA						
Hemigrapsus oregonensis	1					
Corophium sp.	67					
ANNELIDA						
Polychaeta unid.	1					
Total	69	D.I. = 0.15				
STATION Inshore -- SAMPLE A						
ARTHROPODA						
Hemigrapsus oregonensis	1					
Ampelisca sp.	5					
Gnorimosphaeroma oregonensis	1					
Corophium sp.	6					
ANNELIDA						
Polychaete #A.S. 1	10					
Polychaete #A.S. 2	1					
Oligochaeta unid.	14					
Total	38	D.I. = 1.56				
STATION Inshore -- SAMPLE B						
ARTHROPODA						
Hemigrapsus oregonensis	1					
Ampelisca sp.	1					
Corophium sp.	9					
ANNELIDA						
Polychaeta unid.	1					
Total	12	D.I. = 0.83				

APPENDIX A-6

BENTHIC ANIMALS, ANTIOCH
September 14 & 21, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	a/ E.C.	D.O. (ppm)
STATION 2 -- SAMPLE A		20	21.0	6.8	184 : 197	8.2
ARTHROPODA						
Corophium stimpsoni	140					
MOLLUSCA						
Corbicula manilensis	13					
Total	153	D.I. = 0.29				
STATION 2 -- SAMPLE B						
ARTHROPODA						
Corophium stimpsoni	118					
MOLLUSCA						
Corbicula manilensis	16					
Total	134	D.I. = 0.36				
STATION 2 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	220					
MOLLUSCA						
Corbicula manilensis	35					
ANNELIDA						
Oligochaeta						
Tubificids	2					
Total	257	D.I. = 0.44				
STATION 2 -- SAMPLE D						
ARTHROPODA						
Corophium stimpsoni	114					
MOLLUSCA						
Corbicula manilensis	8					
ANNELIDA						
Oligochaeta						
Tubificids	2					
Total	124	D.I. = 0.32				

a/ E.C. values are for low slack and high slack tides

APPENDIX A-6

BENTHIC ANIMALS, ANTIOCH
September 14 & 21, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 3 -- SAMPLE A		20	20.5	7.2	193 : 202	8.8
ARTHROPODA						
Corophium stimpsoni	212					
MOLLUSCA						
Corbicula manilensis	16					
ANNELIDA						
Oligochaeta						
Tubificids	89					
Total	317	D.I. = 0.78				
STATION 3 -- SAMPLE B						
ARTHROPODA						
Corophium stimpsoni	292					
MOLLUSCA						
Corbicula manilensis	2					
ANNELIDA						
Oligochaeta						
Tubificids	113					
Total	404	D.I. = 0.62				
STATION 3 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	275					
MOLLUSCA						
Corbicula manilensis	7					
ANNELIDA						
Oligochaeta						
Tubificids	113					
Total	395	D.I. = 0.68				
STATION 3 -- SAMPLE D						
ARTHROPODA						
Corophium stimpsoni	214					
MOLLUSCA						
Corbicula manilensis	7					
ANNELIDA						
Oligochaeta						
Tubificids	98					
Total	319	D.I. = 0.71				

APPENDIX A-6

BENTHIC ANIMALS, ANTIOCH
September 14 & 21, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 4 -- SAMPLE A		20	20.4	7.8	203 • • 245	8.8
ARTHROPODA						
Corophium stimpsoni	20					
MOLLUSCA						
Corbicula manilensis	10					
ANNELIDA						
Oligochaeta						
Tubificids	14					
Total	44	D.I. = 1.06				
STATION 4 -- SAMPLE B						
ARTHROPODA						
Corophium stimpsoni	35					
MOLLUSCA						
Corbicula manilensis	26					
ANNELIDA						
Oligochaeta						
Tubificids	10					
Total	71	D.I. = 0.99				
STATION 4 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	30					
MOLLUSCA						
Corbicula manilensis	23					
ANNELIDA						
Oligochaeta						
Tubificids	16					
Total	69	D.I. = 1.07				
STATION 4 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	67					
MOLLUSCA						
Corbicula manilensis	114					
ANNELIDA						
Oligochaeta						
Tubificids	7					
Total	188	D.I. = 0.66				

APPENDIX A-6

BENTHIC ANIMALS, ANTIOCH
September 14 & 21, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 5 -- SAMPLE A		20	20.5	8.9	194 • • 288	8.3
ARTHROPODA						
Corophium stimpsoni	174					
MOLLUSCA						
Corbicula manilensis	36					
ANNELIDA						
Oligochaeta						
Tubificids	75					
Total	285	D.I. = 0.92				
STATION 5 -- SAMPLE B						
ARTHROPODA						
Corophium stimpsoni	202					
MOLLUSCA						
Corbicula manilensis	12					
ANNELIDA						
Oligochaeta						
Tubificids	74					
Total	288	D.I. = 0.73				
STATION 5 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	66					
MOLLUSCA						
Corbicula manilensis	21					
ANNELIDA						
Oligochaeta						
Tubificids	55					
Total	142	D.I. = 1.01				
STATION 5 -- SAMPLE D						
ARTHROPODA						
Corophium stimpsoni	218					
MOLLUSCA						
Corbicula manilensis	23					
ANNELIDA						
Neanthes lighti	1					
Oligochaeta						
Tubificids	132					
Total	374	D.I. = 0.85				

APPENDIX A-6

BENTHIC ANIMALS, ANTIOCH
September 14 & 21, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 6 -- SAMPLE A		20	20.5	7.1	200 : 310	7.4
ARTHROPODA						
Corophium stimpsoni	61					
MOLLUSCA						
Corbicula manilensis	37					
ANNELIDA						
Oligochaeta						
Tubificids	2					
Total	100	D.I. = 0.75				
STATION 6 -- SAMPLE B						
ARTHROPODA						
Corophium stimpsoni	116					
MOLLUSCA						
Corbicula manilensis	74					
ANNELIDA						
Oligochaeta						
Tubificids	7					
Total	197	D.I. = 0.80				
STATION 6 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	80					
MOLLUSCA						
Corbicula manilensis	115					
ANNELIDA						
Oligochaeta						
Tubificids	10					
Total	205	D.I. = 0.84				
STATION 6 -- SAMPLE D						
ARTHROPODA						
Corophium stimpsoni	37					
MOLLUSCA						
Corbicula manilensis	82					
ANNELIDA						
Oligochaete						
Tubificids	3					
Total	122	D.I. = 0.75				

APPENDIX A-6

BENTHIC ANIMALS, ANTIOCH
September 14 & 21, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 7 -- SAMPLE A		20	19.8	7.2	218 • • 357	---
ARTHROPODA						
Corophium stimpsoni	1					
MOLLUSCA						
Corbicula manilensis	17					
ANNELIDA						
Oligochaeta						
Tubificids	49					
Total	67	D.I. = 0.64				
STATION 7 -- SAMPLE B						
ARTHROPODA						
Corophium stimpsoni	1					
MOLLUSCA						
Corbicula manilensis	8					
ANNELIDA						
Oligochaeta						
Tubificids	25					
Total	34	D.I. = 0.67				
STATION 7 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	3					
MOLLUSCA						
Corbicula manilensis	33					
ANNELIDA						
Oligochaeta						
Tubificids	25					
Total	61	D.I. = 0.71				
STATION 7 -- SAMPLE D						
MOLLUSCA						
Corbicula manilensis	35					
ANNELIDA						
Oligochaeta						
Tubificids	60					
Total	95	D.I. = 0.66				

APPENDIX A-6

BENTHIC ANIMALS, ANTIOCH
September 14 & 21, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 8 -- SAMPLE A		20	20.0	7.1	232 • 521	---
MOLLUSCA						
Corbicula manilensis	37					
ANNELIDA						
Oligochaeta						
Tubificids	76					
Total	113	D.I. = 0.63				
STATION 8 -- SAMPLE B						
ARTHROPODA						
Corophium stimpsoni	1					
MOLLUSCA						
Corbicula manilensis	10					
ANNELIDA						
Oligochaeta						
Tubificids	28					
Total	39	D.I. = 0.66				
STATION 8 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	2					
MOLLUSCA						
Corbicula manilensis	39					
ANNELIDA						
Oligochaeta						
Tubificids	49					
Total	90	D.I. = 0.82				
STATION 8 -- SAMPLE D						
MOLLUSCA						
Corbicula manilensis	6					
ANNELIDA						
Oligochaeta						
Tubificids	21					
Total	27	D.I. = 0.53				

APPENDIX A-6

BENTHIC ANIMALS, ANTIOCH
September 14 & 21, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 10 -- SAMPLE A		20	21.0	7.2	412 • 629	---
ARTHROPODA						
Ampelisca sp.	1					
MOLLUSCA						
Corbicula manilensis	9					
ANNELIDA						
Oligochaeta						
Tubificids	9					
Total	19	D.I. = 0.87				
STATION 10 -- SAMPLE B						
MOLLUSCA						
Corbicula manilensis	11					
ANNELIDA						
Oligochaeta						
Tubificids	10					
Total	21	D.I. = 0.69				
STATION 10 -- SAMPLE C						
MOLLUSCA						
Corbicula manilensis	13					
ANNELIDA						
Oligochaeta						
Tubificids	16					
Total	29	D.I. = 0.48				
STATION 10 -- SAMPLE D						
MOLLUSCA						
Corbicula manilensis	8					
ANNELIDA						
Oligochaeta						
Tubificids	12					
Total	20	D.I. = 0.67				

APPENDIX A-6

BENTHIC ANIMALS, ANTIOCH
September 14 & 21, 1970

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 12 -- SAMPLE A		20	21.0	7.1	497 • • 757	---
ARTHROPODA						
Corophium stimpsoni	1					
MOLLUSCA						
Corbicula manilensis	14					
ANNELIDA						
Oligochaeta						
Tubificids	2					
Total	17	D.I. = 0.58				
STATION 12 -- SAMPLE B						
MOLLUSCA						
Corbicula manilensis	26					
ANNELIDA						
Oligochaeta						
Tubificids	4					
Total	30	D.I. = 0.39				
STATION 12 -- SAMPLE C						
MOLLUSCA						
Corbicula manilensis	11					
ANNELIDA						
Oligochaeta						
Tubificids	2					
Total	13	D.I. = 0.43				
STATION 12 -- SAMPLE D						
MOLLUSCA						
Corbicula manilensis	15					
ANNELIDA						
Oligochaeta						
Tubificids	1					
Total	16	D.I. = 0.23				

APPENDIX A-7

BENTHIC ANIMALS, ANTIOCH
March 15 & 16, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 1 -- SAMPLE A		20		6.0	220	13.6
ARTHROPODA						
Corophium stimpsoni	231					
MOLLUSCA						
Corbicula manilensis	4					
NEMATODA	1					
ANNELIDA						
Oligochaeta						
Tubificids	36					
Total	272	D.I. = 0.48				
STATION 1 -- SAMPLE B						
ARTHROPODA						
Corophium stimpsoni	264					
MOLLUSCA						
Corbicula manilensis	33					
ANNELIDA						
Oligochaeta						
Tubificids	42					
Total	339	D.I. = 0.69				
STATION 1 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	324					
MOLLUSCA						
Corbicula manilensis	48					
ANNELIDA						
Oligochaeta						
Tubificids	41					
Total	413	D.I. = 0.67				
STATION 1 -- SAMPLE D						
ARTHROPODA						
Corophium stimpsoni	232					
MOLLUSCA						
Corbicula manilensis	79					
ANNELIDA						
Oligochaeta						
Tubificids	41					
Total	359	D.I. = 0.88				

APPENDIX A-7

BENTHIC ANIMALS, ANTIOCH
March 15 & 16, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 2 -- SAMPLE A		20		6.0	192	12.2
ARTHROPODA						
Corophium stimpsoni	137					
MOLLUSCA						
Corbicula manilensis	114					
ANNELIDA						
Oligochaeta						
Tubificids	176					
Oligochaete A1	1					
Total	438	D.I. = 1.09				
STATION 2 -- SAMPLE B						
ARTHROPODA						
Corophium stimpsoni	92					
MOLLUSCA						
Corbicula manilensis	75					
ANNELIDA						
Oligochaete A1	15					
Oligochaete A2	25					
Oligochaete A3	7					
Tubificids	46					
Total	260	D.I. = 1.51				
STATION 2 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	148					
MOLLUSCA						
Corbicula manilensis	136					
ANNELIDA						
Oligochaeta						
Tubificids	132					
Total	416	D.I. = 1.10				
STATION 2 -- SAMPLE D						
ARTHROPODA						
Corophium stimpsoni	146					
MOLLUSCA						
Corbicula manilensis	83					
ANNELIDA						
Oligochaeta						
Tubificids	104					
Total	333	D.I. = 1.07				

APPENDIX A-7

BENTHIC ANIMALS, ANTIOCH
March 15 & 16, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 4 -- SAMPLE A		20		6.7	175	9.8
ARTHROPODA						
Corophium stimpsoni	236					
MOLLUSCA						
Corbicula manilensis	119					
ANNELIDA						
Oligochaete A1	2					
Oligochaete A2	22					
Tubificids	60					
Total	439	D.I. = 1.13				
STATION 4 -- SAMPLE B						
ARTHROPODA						
Corophium stimpsoni	37					
MOLLUSCA						
Corbicula manilensis	265					
ANNELIDA						
Oligochaeta						
Tubificids	49					
Total	351	D.I. = 0.72				
STATION 4 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	231					
MOLLUSCA						
Corbicula manilensis	147					
NEMATODA	3					
ANNELIDA						
Oligochaeta						
Tubificids	88					
Total	469	D.I. = 1.05				
STATION 4 -- SAMPLE D						
ARTHROPODA						
Corophium stimpsoni	261					
MOLLUSCA						
Corbicula manilensis	170					
ANNELIDA						
Oligochaeta						
Tubificids	60					
Total	491	D.I. = 0.96				

APPENDIX A-7

BENTHIC ANIMALS, ANTIOCH
March 15 & 16, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 5 -- SAMPLE A		20		7.0	191	9.8
ARTHROPODA						
Corophium stimpsoni	68					
MOLLUSCA						
Corbicula manilensis	73					
NEMATODA	18					
ANNELIDA						
Oligochaeta						
Tubificids	46					
Total	205	D.I. = 1.28				
STATION 5 -- SAMPLE B						
ARTHROPODA						
Corophium stimpsoni	88					
MOLLUSCA						
Corbicula manilensis	67					
ANNELIDA						
Oligochaeta						
Tubificids	27					
Total	182	D.I. = 1.00				
STATION 5 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	52					
MOLLUSCA						
Corbicula manilensis	5					
ANNELIDA						
Oligochaeta						
Tubificids	30					
Total	87	D.I. = 0.84				

APPENDIX A-7

BENTHIC ANIMALS, ANTIOCH
March 15 & 16, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 6 -- SAMPLE A		20		7.0	198	9.8
ARTHROPODA						
Corophium stimpsoni	52					
MOLLUSCA						
Corbicula manilensis	37					
ANNELIDA						
Oligochaeta						
Tubificids	9					
Total	98	D.I. = 0.92				
STATION 6 -- SAMPLE B						
ARTHROPODA						
Corophium stimpsoni	57					
MOLLUSCA						
Corbicula manilensis	31					
ANNELIDA						
Oligochaeta						
Tubificids	16					
Total	104	D.I. = 0.98				
STATION 6 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	53					
MOLLUSCA						
Corbicula manilensis	69					
ANNELIDA						
Oligochaeta						
Tubificids	18					
Total	140	D.I. = 0.98				
STATION 6 -- SAMPLE D						
ARTHROPODA						
Corophium stimpsoni	40					
MOLLUSCA						
Corbicula manilensis	36					
ANNELIDA						
Oligochaeta						
Tubificids	28					
NEMATODA	1					
Total	105	D.I. = 1.13				

APPENDIX A-7

BENTHIC ANIMALS, ANTIOCH
March 15 & 16, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 7 -- SAMPLE A		20		7.1	211	10.2
ARTHROPODA						
Corophium stimpsoni	67					
MOLLUSCA						
Corbicula manilensis	164					
ANNELIDA						
Oligochaeta						
Tubificids	70					
Total	301	D.I. = 1.00				
STATION 7 -- SAMPLE B						
ARTHROPODA						
Corophium stimpsoni	5					
MOLLUSCA						
Corbicula manilensis	183					
ANNELIDA						
Oligochaeta						
Tubificids	33					
NEMATODA	7					
Total	228	D.I. = 0.57				
STATION 7 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	12					
MOLLUSCA						
Corbicula manilensis	104					
ANNELIDA						
Polychaeta unid.	1					
Oligochaeta						
Tubificids	65					
Total	182	D.I. = 0.89				
STATION 7 -- SAMPLE D						
ARTHROPODA						
Corophium stimpsoni	2					
MOLLUSCA						
Corbicula manilensis	330					
ANNELIDA						
Oligochaeta						
Tubificids	9					
Total	341	D.I. = 0.15				

APPENDIX A-7

BENTHIC ANIMALS, ANTIOCH
March 15 & 16, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 8 -- SAMPLE A		20		6.3	269	9.8
ARTHROPODA						
Corophium stimpsoni	1					
MOLLUSCA						
Corbicula manilensis	21					
ANNELIDA						
Oligochaeta						
Tubificids	4					
Total	26	D.I. = 0.58				
STATION 8 -- SAMPLE B						
ARTHROPODA						
Corophium stimpsoni	1					
MOLLUSCA						
Corbicula manilensis	35					
ANNELIDA						
Oligochaeta						
Tubificids	2					
Total	38	D.I. = 0.32				
STATION 8 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	1					
MOLLUSCA						
Corbicula manilensis	46					
ANNELIDA						
Oligochaeta						
Tubificids	2					
Total	49	D.I. = 0.13				
STATION 8 -- SAMPLE D						
ARTHROPODA						
Corophium stimpsoni	3					
MOLLUSCA						
Corbicula manilensis	31					
ANNELIDA						
Oligochaeta						
Tubificids	4					
Total	38	D.I. = 0.60				

APPENDIX A-7

BENTHIC ANIMALS, ANTIOCH
March 15 & 16, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 9 -- SAMPLE A		20		6.6	302	9.6
ARTHROPODA						
Corophium stimpsoni	3					
MOLLUSCA						
Corbicula manilensis	6					
ANNELIDA						
Oligochaete Al	1					
Tubificids	30					
Total	40	D.I. = 0.78				
STATION 9 -- SAMPLE B						
ARTHROPODA						
Corophium stimpsoni	8					
MOLLUSCA						
Corbicula manilensis	14					
ANNELIDA						
Oligochaeta						
Tubificids	93					
Total	115	D.I. = 0.61				
STATION 9 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	7					
MOLLUSCA						
Corbicula manilensis	31					
ANNELIDA						
Oligochaete Al	5					
Tubificids	63					
Polychaete Al	3					
Total	109	D.I. = 1.08				
STATION 9 -- SAMPLE D						
ARTHROPODA						
Corophium stimpsoni	1					
MOLLUSCA						
Corbicula manilensis	15					
ANNELIDA						
Oligochaeta						
Tubificids	66					
Total	82	D.I. = 0.54				

APPENDIX A-7

BENTHIC ANIMALS, ANTIOCH
March 15 & 16, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 11 -- SAMPLE A		20		6.8	336	9.2
ARTHROPODA						
Corophium stimpsoni	2					
MOLLUSCA						
Corbicula manilensis	25					
ANNELIDA						
Oligochaeta						
Tubificids	13					
Total	40	D.I. = 0.81				
STATION 11 -- SAMPLE B						
MOLLUSCA						
Corbicula manilensis	7					
ANNELIDA						
Oligochaeta						
Tubificids	7					
Total	14	D.I. = 0.69				
STATION 11 -- SAMPLE C						
MOLLUSCA						
Corbicula manilensis	40					
ANNELIDA						
Oligochaeta						
Tubificids	8					
NEMATODA	4					
Total	52	D.I. = 0.68				
STATION 11 -- SAMPLE D						
ARTHROPODA						
Corophium stimpsoni	2					
MOLLUSCA						
Corbicula manilensis	4					
ANNELIDA						
Oligochaeta						
Tubificids	15					
Total	21	D.I. = 0.78				

APPENDIX A-7

BENTHIC ANIMALS, ANTIOCH
March 15 & 16, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 12 -- SAMPLE A		20		6.9	297	8.8
ARTHROPODA						
Corophium stimpsoni	465					
MOLLUSCA						
Corbicula manilensis	143					
ANNELIDA						
Oligochaete A3	12					
Tubificids	130					
Polydora uncata	1					
Polychaete A1	1					
Total	753	D.I. = 0.99				
STATION 12 -- SAMPLE B						
ARTHROPODA						
Corophium stimpsoni	4					
MOLLUSCA						
Corbicula manilensis	9					
ANNELIDA						
Oligochaeta						
Tubificids	95					
Polychaete A3	1					
Total	109	D.I. = 0.49				
STATION 12 -- SAMPLE C						
MOLLUSCA						
Corbicula manilensis	29					
ANNELIDA						
Oligochaeta						
Tubificids	38					
Total	67	D.I. = 0.68				
STATION 12 -- SAMPLE D						
ARTHROPODA						
Corophium stimpsoni	212					
MOLLUSCA						
Corbicula manilensis	37					
ANNELIDA						
Oligochaete A2	1					
Tubificids	283					
Polychaete A3	2					
NEMATODA	4					
Total	539	D.I. = 0.94				

APPENDIX A-7

BENTHIC ANIMALS, ANTIOCH
March 15 & 16, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 13 -- SAMPLE A		20		7.0	278	8.0
MOLLUSCA						
Corbicula manilensis	14					
ANNELIDA						
Oligochaeta						
Tubificids	73					
Total	87	D.I. = 0.44				
STATION 13 -- SAMPLE B						
MOLLUSCA						
Corbicula manilensis	11					
ANNELIDA						
Oligochaeta						
Tubificids	5					
NEMATODA	2					
Total	18	D.I. = 0.90				
STATION 13 -- SAMPLE C						
MOLLUSCA						
Corbicula manilensis	17					
ANNELIDA						
Oligochaeta						
Tubificids	5					
Total	22	D.I. = 0.54				
STATION 13 -- SAMPLE D						
MOLLUSCA						
Corbicula manilensis	131					
ANNELIDA						
Oligochaeta						
Tubificids	7					
Total	138	D.I. = 0.20				

APPENDIX A-7

BENTHIC ANIMALS, ANTIOCH
March 15 & 16, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 14 -- SAMPLE A		20		7.2	218	8.2
ARTHROPODA						
Corophium stimpsoni	2					
MOLLUSCA						
Corbicula manilensis	26					
ANNELIDA						
Oligochaeta						
Tubificids	27					
Total	55	D.I. = 0.82				
STATION 14 -- SAMPLE B						
MOLLUSCA						
Corbicula manilensis	50					
ANNELIDA						
Oligochaeta						
Tubificids	9					
Total	59	D.I. = 0.43				
STATION 14 -- SAMPLE C						
ARTHROPODA						
Corophium stimpsoni	2					
MOLLUSCA						
Corbicula manilensis	82					
ANNELIDA						
Oligochaeta						
Tubificids	6					
Total	90	D.I. = 0.35				
STATION 14 -- SAMPLE D						
MOLLUSCA						
Corbicula manilensis	6					
ANNELIDA						
Oligochaeta						
Tubificids	3					
Total	9	D.I. = 0.64				

APPENDIX A-8

BENTHIC ANIMALS, SOUTH BAY
April 14, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 1 -- SAMPLE A			15.0	7.9	346.1	8.0
ARTHROPODA						
Ampelisca sp.	243					
Corophium sp.	3					
MOLLUSCA						
Modiolus sp.	2					
ANNELIDA						
Oligochaeta						
Tubificids	30					
Streblospio benedicti	1					
Polychaeta unid.	4					
Total	283					
STATION 1 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	279					
Corophium sp.	24					
MOLLUSCA						
Tapes semidecussata	2					
Crepidula perforans	1					
Modiolus sp.	14					
ANNELIDA						
Polychaeta unid.	9					
Total	329					
STATION 1 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	350					
Corophium sp.	4					
NEMATODA	4					
MOLLUSCA						
Modiolus sp.	2					
ANNELIDA						
Streblospio benedicti	33					
Polychaeta unid.	42					
Oligochaeta						
Tubificids	13					
Total	448					
STATION 2 -- SAMPLE A			14.5	8.3	346.1	9.0
ARTHROPODA						
Ampelisca sp.	312					
Corophium sp.	21					

APPENDIX A-8

BENTHIC ANIMALS, SOUTH BAY
April 14, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
CNIDARIA						
Metridium senile	7					
ANNELIDA						
Polychaeta unid.	3					
Streblospio benedicti	11					
Oligochaeta						
Tubificids	9					
MOLLUSCA						
Tapes semidecussata	1					
Crepidula perforans	1					
Gemma gemma	3					
Mya arenaria	4					
Modiolus sp.	63					
Total	435					
STATION 2 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	137					
Corophium sp.	4					
ANNELIDA						
Streblospio benedicti	11					
Polychaeta unid.	1					
Oligochaeta						
Tubificids	22					
Total	184					
STATION 2 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	153					
Corophium sp.	4					
ANNELIDA						
Streblospio benedicti	2					
Oligochaeta						
Tubificids	6					
MOLLUSCA						
Gemma gemma	4					
Modiolus sp.	23					
Total	192					
STATION 3 -- SAMPLE A			14.5	8.1	346.1	8.8
ARTHROPODA						
Ampelisca sp.	1					

APPENDIX A-8

BENTHIC ANIMALS, SOUTH BAY
April 14, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
ANNELIDA						
Streblospio benedicti	1					
Oligochaeta						
Tubificids	24					
Total	26					
STATION 3 -- SAMPLE B						
ANNELIDA						
Oligochaeta						
Tubificids	18					
MOLLUSCA						
Modiolus sp.	2					
Tapes semidecussata	1					
Total	21					
STATION 4 -- SAMPLE A			14.5	7.8	334.7	8.6
ARTHROPODA						
Ampelisca sp.	1					
ANNELIDA						
Streblospio benedicti	14					
Polychaeta unid.	7					
Oligochaeta						
Tubificids	319					
MOLLUSCA						
Gemma gemma	6					
Modiolus sp.	2					
Tapes semidecussata	3					
Total	352					
STATION 4 -- SAMPLE B						
ANNELIDA						
Polychaeta unid.	8					
Streblospio benedicti	2					
Oligochaeta						
Tubificids	108					
MOLLUSCA						
Tapes semidecussata	3					
Modiolus sp.	10					
Mya arenaria	1					
Total	132					

APPENDIX A-8

BENTHIC ANIMALS, SOUTH BAY
April 14, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 4 -- SAMPLE C						
ANNELIDA						
Streblospio benedicti	2					
Polychaeta unid.	4					
Oligochaeta						
Tubificids	156					
MOLLUSCA						
Modiolus sp.	1					
Gemma gemma	1					
Total	164					
STATION 5 -- SAMPLE A			14.0	8.0	346.1	8.0
ARTHROPODA						
Ampelisca	34					
ANNELIDA						
Polychaeta unid.	18					
Oligochaeta						
Tubificids	178					
MOLLUSCA						
Gemma gemma	1,242					
Mya arenaria	2					
Modiolus sp.	5					
Total	1,459					
STATION 5 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	48					
Corophium sp.	13					
CNIDARIA						
Metridium senile	2					
ANNELIDA						
Polychaeta unid.	17					
Oligochaeta						
Tubificids	154					
MOLLUSCA						
Modiolus sp.	14					
Gemma gemma	1,568					
Macoma sp.	2					
Crepidula perforans	2					
Total	1,820					

APPENDIX A-8

BENTHIC ANIMALS, SOUTH BAY
April 14, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 5 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	47					
Corophium sp.	4					
ANNELIDA						
Streblospio benedicti	21					
Polychaeta unid.	222					
Oligochaeta unid.	1					
MOLLUSCA						
Gemma gemma	1,781					
Modiolus sp.	12					
Mya arenaria	1					
Macoma sp.	1					
Odostomia sp.	1					
Total	2,201					
STATION 6 -- SAMPLE A			14	7.7	341.0	7.7
ARTHROPODA						
Ampelisca sp.	63					
Corophium sp.	1					
MOLLUSCA						
Modiolus sp.	10					
Gemma gemma	716					
Macoma sp.	7					
Mya arenaria	1					
ANNELIDA						
Streblospio benedicti	2					
Polychaeta unid.	41					
NEMATODA	1					
Total	846					
STATION 6 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	6					
Corophium sp.	1					
MOLLUSCA						
Gemma gemma	15					
ANNELIDA						
Streblospio benedicti	1					
Polychaeta unid.	6					
Oligochaeta Tubificids	16					
Total	45					

APPENDIX A-8

BENTHIC ANIMALS, SOUTH BAY
April 14, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 6 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	11					
ANNELIDA						
Polychaeta unid.	199					
MOLLUSCA						
Gemma gemma	332					
Macoma sp.	3					
Mya arenaria	2					
Modiolus sp.	1					
Total	548					
STATION 7 -- SAMPLE A			14.0	7.6	328.4	7.3
ARTHROPODA						
Ampelisca sp.	91					
Synidotea laticauda	1					
MOLLUSCA						
Gemma gemma	4,071					
Modiolus sp.	5					
Macoma sp.	12					
Acteon sp.	4					
Mya arenaria	3					
CNIDARIA						
Metridium sp.	1					
ANNELIDA						
Polychaeta unid.	2					
Oligochaeta						
Tubificids	12					
Total	4,200					
STATION 7 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	66					
MOLLUSCA						
Gemma gemma	938					
Mya arenaria	1					
Macoma sp.	21					
Modiolus sp.	3					
ANNELIDA						
Oligochaeta						
Tubificids	30					
Polychaeta unid.	5					
Total	1,064					

APPENDIX A-8

BENTHIC ANIMALS, SOUTH BAY
April 14, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 7 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	140					
NEMATODA	2					
MOLLUSCA						
Gemma gemma	2,915					
Macoma sp.	11					
Mya arenaria	2					
Acteon sp.	2					
ANNELIDA						
Polychaeta unid.	98					
Streblospio benedicti	12					
Total	3,182					
STATION 8 -- SAMPLE A			14.0	7.3	303.1	6.8
MOLLUSCA						
Gemma gemma	6					
ANNELIDA						
Oligochaeta						
Tubificids	88					
Streblospio benedicti	18					
Total	112					
STATION 8 -- SAMPLE B						
ARTHROPODA						
Hemigrapsus oregonensis	1					
MOLLUSCA						
Gemma gemma	2					
ANNELIDA						
Polychaeta unid.	1					
Oligochaeta						
Tubificids	363					
Streblospio benedicti	18					
Total	385					
STATION 8 -- SAMPLE C						
MOLLUSCA						
Mya arenaria	2					
ANNELIDA						
Streblospio benedicti	10					
Oligochaeta						
Tubificids	145					
Total	157					

APPENDIX A-8

BENTHIC ANIMALS, SOUTH BAY
April 14, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 9 -- SAMPLE A			14.5	7.4	227.3	5.8
ANNELIDA						
Streblospio benedicti	2					
Oligochaeta						
Tubificids	44					
Total	46					
STATION 9 -- SAMPLE B						
MOLLUSCA						
Gemma gemma	1					
ANNELIDA						
Streblospio benedicti	2					
Oligochaeta						
Tubificids	11					
Total	14					
STATION 9 -- SAMPLE C						
MOLLUSCA						
Gemma gemma	1					
ANNELIDA						
Oligochaeta						
Tubificids	3					
Total	4					

APPENDIX A-9

BENTHIC ANIMALS, LOWER BAY
April 14, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 2 -- SAMPLE A		31	14	8.0	346.1	7.6
ARTHROPODA						
Ampelisca sp.	5					
Corophium sp.	11					
Leptochelia sp.	42					
Balanus sp.	3					
MOLLUSCA						
Ostrea lurida	3					
Modiolus sp.	2					
Mytilus edulis	1					
Gemma gemma	4					
ANNELIDA						
Polychaeta unid.	101					
Oligochaeta						
Tubificids	17					
NEMATODA	8					
CHORDATA						
Tunicata	2					
NEMERTEA	1					
Total	200					
STATION 2 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	4					
Corophium sp.	19					
Leptochelia sp.	24					
MOLLUSCA						
Tapes semidecussata	1					
Macoma sp.	1					
ANNELIDA						
Polychaeta unid.	52					
Oligochaeta						
Tubificids	33					
CNIDARIA						
Metridium sp.	1					
NEMERTEA	8					
NEMATODA	2					
Total	145					
STATION 2 -- SAMPLE C						
ARTHROPODA						
Corophium sp.	6					
Balanus sp.	1					
Leptochelia sp.	20					

APPENDIX A-9

BENTHIC ANIMALS, LOWER BAY
April 14, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
MOLLUSCA						
Gemma gemma	2					
ANNELIDA						
Polychaeta unid.	42					
Oligochaeta						
Tubificids	32					
CHORDATA						
Tunicata	1					
CNIDARIA						
Metridium sp.	1					
NEMATODA	3					
NEMERTEA	2					
Total	110					
STATION 3 -- SAMPLE A		30	14	8.2	346.1	7.8
ARTHROPODA						
Corophium sp.	7					
Leptochelia sp.	121					
MOLLUSCA						
Tapes semidecussata	11					
ANNELIDA						
Polychaeta unid.	32					
Oligochaeta						
Tubificids	40					
CHORDATA						
Tunicata	3					
CNIDARIA						
Metridium sp.	9					
NEMATODA	2					
Total	225					
STATION 3 -- SAMPLE B						
ARTHROPODA						
Corophium sp.	5					
Leptochelia sp.	18					
MOLLUSCA						
Tapes semidecussata	35					
Modiolus sp.	1					
Odostomia sp.	2					
ANNELIDA						
Polychaeta unid.	25					
Oligochaeta unid.	14					
Oligochaeta						
Tubificids	25					

APPENDIX A-9

BENTHIC ANIMALS, LOWER BAY
April 14, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
CNIDARIA						
Metridium sp.	8					
NEMATODA	6					
Total	141					
STATION 3 -- SAMPLE C						
ARTHROPODA						
Corophium sp.	4					
Leptochelia sp.	25					
Pagurus samuelis	1					
MOLLUSCA						
Tapes semidecussata	15					
ANNELIDA						
Polychaeta unid.	174					
Oligochaeta						
Tubificids	55					
NEMATODA	6					
Total	280					
STATION 4 -- SAMPLE A		6	15.5	8.1		8.0
ARTHROPODA						
Ampelisca sp.	501					
Corophium sp.						
MOLLUSCA						
Modiolus sp.	69					
Gemma gemma	15					
Macoma sp.	1					
ANNELIDA						
Polychaeta unid.	41					
Oligochaeta						
Tubificids	42					
Total	748					
STATION 4 -- SAMPLE B						
ARTHROPODA						
Ampelisca sp.	226					
Corophium sp.	20					
MOLLUSCA						
Gemma gemma	11					
Modiolus demissus	5					
ANNELIDA						
Polychaeta unid.	61					
Oligochaeta						
Tubificids	45					
NEMATODA	3					
Total	371					

APPENDIX A-9

BENTHIC ANIMALS, LOWER BAY
April 14, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 4 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	332					
Corophium sp.	24					
Synidotea laticauda	1					
MOLLUSCA						
Tapes semidecussata	1					
Modiolus sp.	40					
Gemma gemma	4					
ANNELIDA						
Polycheata unid.	119					
NEMATODA	1					
Total	522					
STATION 6 -- SAMPLE A		49	14	8.2	347.3	7.8
ARTHROPODA						
Ampelisca sp.	4					
Corophium sp.	2					
Synidotea laticauda	1					
MOLLUSCA						
Mya arenaria	1					
Tapes semidecussata	89					
ANNELIDA						
Oligochaeta						
Tubificids	31					
NEMATODA	59					
Total	187					
STATION 6 -- SAMPLE B						
ARTHROPODA						
Leptochelia	1					
MOLLUSCA						
Tapes semidecussata	100					
Modiolus sp.	1					
Cardium sp.	26					
ANNELIDA						
Polychaeta unid.	244					
Oligochaeta						
Tubificids	33					
Tubiculous	16					
NEMATODA	437					
CNIDARIA						
Metridium sp.	1					
Total	859					

APPENDIX A-9

BENTHIC ANIMALS, LOWER BAY
April 14, 1971

Individual Animals Genera and Species	Number Present	Depth (ft.)	Temp. (°C)	pH	E.C.	D.O. (ppm)
STATION 6 -- SAMPLE C						
ARTHROPODA						
Ampelisca sp.	1					
Leptochelia sp.	1					
MOLLUSCA						
Tapes semidecussata	81					
Modiolus sp.	4					
Macoma sp.	1					
ANNELIDA						
Polychaeta unid.	138					
Oligochaeta						
Tubificids	105					
Tubiculous	23					
NEMATODA	318					
Total	672					

APPENDIX B-1

STANDARD OIL
SUBSTRATE COMPOSITION ANALYSIS

	Percent Retained by Screen					
	Screen Size					
Station	8 (2.38 mm)	16 (1.19mm)	50 (0.297 mm)	100 (0.149 mm)	270 (0.053 mm)	>270
1	0	0	3	2	20	75
2	0	1	2	2	24	71
3	0	0	1	1	20	78
4	1	1	7	4	6	81
5	0	0	2	4	16	78
6	1	2	5	4	31	57
7	1	1	2	4	8	84

APPENDIX B-2

SUBSTRATE COMPOSITION ANALYSIS
Mt. Copper

	Percent Retained by Screen Size					
Station	8 (2.38 mm)	16 (1.19 mm)	50 (0.297 mm)	100 (0.149 mm)	270 (0.053 mm)	>270
Mc-1	0	0	4	11	39	46
Mc-2	0	0	1	38	6	55
Mc-3	0	0	1	0	9	90
Mc-4	0	0	1	5	22	72
Mc-5	0	0	1	1	14	84
Mc-6	0	0	1	2	7	90
Mc-7	0	0	3	16	11	70
Mc-8	0	0	0	1	0	99

APPENDIX B-3

SUBSTRATE COMPOSITION ANALYSIS
San Leandro - October 30, 1970

Station	Percent Retained by Screen Size					
	8 (2.38 mm)	16 (1.19 mm)	50 (0.297 mm)	100 (0.149 mm)	270 (0.053 mm)	>270
98	0	0	1	0	0	99
61	1	1	6	12	8	72
73	0	0	1	1	2	96
85	0	1	7	5	6	81
84	9	14	7	2	5	63
112	22	15	10	3	5	45
108	23	20	13	4	4	36

APPENDIX B-6

SUBSTRATE COMPOSITION ANALYSIS
Antioch - September 14 & 21, 1970

	Percent Retained by Screen					
	Screen Size					
Station	8 (2.38 mm)	16 (1.19 mm)	50 (0.297 mm)	100 (0.149 mm)	270 (0.053 mm)	> 270
2	0	0	2	76	20	2
3	0	0	4	43	47	6
4	0	0	1	83	15	1
5	0	0	9	69	21	1
6	1	2	85	9	2	1
7	0	2	76	17	4	1
8	0	1	25	62	9	3
10	0	0	0	69	30	1
12	0	0	51	47	1	1

APPENDIX B-7

SUBSTRATE COMPOSITION ANALYSIS
Antioch - March 15 & 16, 1971

Station	Percent Retained by Screen Size					
	8 (2.38 mm)	16 (1.19 mm)	50 (0.297 mm)	100 (0.149 mm)	270 (0.053 mm)	> 270
1	0	0	1	30	50	19
2	0	0	1	3	79	17
4	0	0	1	38	48	13
5	0	0	1	72	26	1
6	0	0	1	38	58	3
7	0	4	66	6	4	20
8	0	0	6	89	4.8	.2
9	0	1	43	41	12	3
11	0	0	67	32.2	.8	.0
12	0	0	42	53	4	1
13	0	1	90	8	.7	.3
14	0	0	4	81	14.6	.4

APPENDIX B-8

SUBSTRATE COMPOSITION ANALYSIS
South Bay

Station	Percent Retained by Screen Size						
	<8	8 (2.38 mm)	16 (1.19 mm)	50 (0.297mm)	100 (0.149 mm)	270 (0.053 mm)	> 270
1	0	1	1	2	4	8	84
2	0	0	1	1	2	6	90
3	3	16	11	10	8	7	36
4	0	2	3	31	12	1	51
5	0	0	2	2	1	4	91
6	0	0	1	2	1	2	94
7	0	0	1	2	1	2	94
8	0	0	0	0	0	1	99
9	0	0	0	1	2	2	95

APPENDIX B-9

SUBSTRATE COMPOSITION ANALYSIS
Lower Bay

Station	Percent Retained by Screen Size					
	8 (2.38 mm)	16 (1.19 mm)	50 (0.297 mm)	100 (0.149 mm)	270 (0.053 mm)	> 270
2	1	2	17	18	7	55
3	9	5	16	26	6	38
4	0	0	0	1	1	98
6	15	6	39	18	1	21

APPENDIX C-1

STANDARD OIL SEDIMENT CHEMICAL ANALYSIS

	Station 1	2	3	4	5	6	7
Nitrate*	2.3	2.7	3.1	1.5	3.2	2.9	3.1
Organic Carbon*	17,000	11,000	9,000	28,000	20,000	17,000	13,000
Ammonia plus Org. N*	1,780	1,000	1,400	2,010	1,350	1,100	1,080
Grease and Oil*	490	710	1,730	930	2,100	650	415
B O D*	2,300	4,600	6,400	11,000	4,500	3,400	3,200
Available Arsenic*	0.0	0.4	0.1	0.5	0.1	0.0	0.1
Available Cadmium*	0.2	0.1	0.0	0.0	0.0	0.0	0.0
Available Chromium*	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Available Copper*	0.3	0.1	0.2	0.1	0.2	0.1	0.1
Available Iron*	13	5.8	15	3.0	10	0.0	2.3
Available Lead*	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Available Zinc*	0.0	0.0	0.0	0.5	0.0	0.0	0.0
Total Mercury*	0.50	0.38	0.45	1.1	0.64	0.33	0.34
Loss on Ignition %	7.3	5.2	5.8	8.3	6.1	5.4	4.9
Percent Waste	0.3	1.7	2.2	4.0	1.3	3.0	2.0

Mg/Kg * dry weight basis

85254 983 9/73 1M OSP

APPENDIX C-2

MOUNTAIN COPPER SUBSTRATE CHEMICAL ANALYSIS

Sta.	Arsenic Mg/Kg* Avail.	Arsenic Mg/Kg* Total	Cadmium Mg/Kg* Avail.	Cadmium Mg/Kg* Total	Chromium Mg/Kg* Avail.	Chromium Mg/Kg* Total	Copper Mg/Kg* Avail.	Copper Mg/Kg* Total	Iron Mg/Kg* Avail.	Iron Mg/Kg* Total	Lead Mg/Kg* Avail.	Lead Mg/Kg* Total	Zinc Mg/Kg* Avail.	Zinc Mg/Kg* Total	Grease & Oil Mg/Kg* Avail.	Grease & Oil Mg/Kg* Total
1	0.2	24	0.0	.02	0.0	16	0.4	1.5	0.0	7,350	0.0	22	1.8	14	715	-
2	0.2	32	0.0	0.5	0.0	32	0.1	5.8	6.7	13,200	0.0	19	0.6	40	365	-
3	0.3	33	0.0	0.5	0.0	40	0.2	3.8	3.2	13,400	0.0	21	0.4	32	3,200	-
4	0.1	36	0.0	0.5	0.0	32	0.1	5.8	0.0	12,200	0.0	2.0	0.8	34	635	-
5	0.2	58	0.3	0.5	0.0	34	3.2	4.9	118	17,000	0.0	24	26	47	1,100	-
6	0.2	67	0.2	0.6	0.0	33	0.4	3.4	220	14,200	0.0	19	15	35	1,600	-
7	0.6	35	0.2	2.6	0.0	37	0.3	9.6	0.0	15,000	0.0	25	21	338	550	-
8	0.3	43	1.6	3.1	0.0	123	1.2	42	201	37,000	.09	33	233	1,080	1,640	-

* Dry weight basis.

CALIFORNIA

The Resources Agency
STATE WATER RESOURCES CONTROL BOARD
1416 Ninth Street, Sacramento, California 95814

CALIFORNIA REGIONAL
WATER QUALITY CONTROL BOARDS

NORTH COAST REGION (1)
Suite F, 2200 County Center Drive
Santa Rosa, California 95401

SAN FRANCISCO BAY REGION (2)
364 14th Street
Oakland, California 94612

CENTRAL COAST REGION (3)
2238 Broad Street
San Luis Obispo, California 93401

LOS ANGELES REGION (4)
Room 4027, 107 South Broadway
Los Angeles, California 90012

CENTRAL VALLEY REGION (5)
3201 S Street
Sacramento, California 95816

FRESNO BRANCH OFFICE
(Central Valley Region)
3374 Shields Avenue, (P. O. Box 2188)
Fresno, California 93719

LAHONTAN REGION (6)
407 West Line Street
Bishop, California 93514

LAKE TAHOE BRANCH OFFICE
(Lahontan Region)
1014 Blue Lake Avenue, Suite 3
(P. O. Box 3329)
South Lake Tahoe, California 95705

COLORADO RIVER BASIN REGION (7)
81–715 Highway 111 (P. O. Drawer 1)
Indio, California 92201

SANTA ANA REGION (8)
6848 Magnolia Avenue, Suite 4
Riverside, California 92506

SAN DIEGO REGION (9)
6154 Mission Gorge Road, Suite 205
San Diego, California 92120

UNIVERSITY OF ILLINOIS-URBANA
3 0112 101474713